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COMPUTER AIDED PARAMETRIC SONAR DESIGN.(U)
MAY 73 E C GANNON, R P PINGREE
UNCLASSIFIED NUSC-TM-TDIX-33-73 NL

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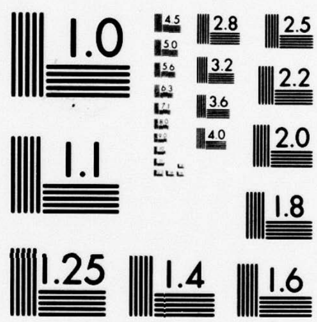

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TM No.
NUSC-TM-TD1X-33-73

NAVAL UNDERWATER SYSTEMS CENTER
Newport, Rhode Island 02840

Technical Memo

COMPUTER AIDED PARAMETRIC SONAR DESIGN

23 May 1973

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ABSTRACT

A computer program was written that enables the design of parametric sonars. This program accepts as inputs temperature, salinity, depth, estimates of projector area, desired secondary source level and secondary frequency. The program computes various parametric sonar quantities among them primary source level, directivity index and primary operating frequency. The program actually generates a matrix of possible design values that permit the designer to choose those which best suit his needs based on other system considerations.

The design program is written in Fortran V for use on the Univac 1108. The program is completely general and any of the input parameters can be varied while holding the others constant. A discussion on how to use the program as well as a sample example is included.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under Project No. A-614-19, Principal Investigator, Dr. A. J. Van Woerkum, Code TC.

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INTRODUCTION

From the viewpoint of the individual who is faced with the design of a parametric sonar, the calculations involved seem repetitive and in some cases endless. The Mellen and Moffett[1] curves together with the appropriate equations given in the reference contain all of the necessary information. However, the information is presented in such a way as to make it easy to work through the curves and calculations to analyze the parametric operation of existing projectors and systems but it is difficult and not straightforward to work backward through the curves and equations to design a projector system.

There is a solution which is offered by Moffett[2] that uses a "load line" type of technique similar to that used in vacuum tube circuit design. This is good for a small number of possible designs of a given parametric sonar. The method requires, however, repetitive computations to arrive at the dimensionless parameters 1/(2)(AL)(RO) for each possible parametric stepdown ratio (the ratio of the parametric difference frequency to the mean projector driving frequency FO/F). The term (AL) is absorption in nepers per meter while RO is the Rayleigh distance. Appendix B contains a complete glossary of terms. The "load line" method is presently limited by the number of families of curves available for the different stepdown ratios and the accuracy of interpolating between the given curves of a given family.

A means, therefore, was devised where the whole design process was automated using the Univac 1108 computer. In essence, computer aided design. The solution allows the designer to work from a known secondary source level (LSS) and a known secondary frequency (F) for a range of values of projector size (A), primary source level per tone (LSP) and a given stepdown ratio (FO/F). The computer program will build a matrix of possible designs that can then be compared with other factors to achieve a workable and realistic design.

BACKGROUND

In parametric sonar calculations, two distinct and different problems arise. One is that of the analysis of existing sonar to predict their parametric operating characteristics. The other is the design of parametric sonars having a given set or range of output source levels and frequencies.

In the first problem, one usually knows the primary operating frequency (FO), the primary source level (LSP), and the projector area (A). From these one obtains the secondary source level (LSS) and secondary directivity index (NDIS) for a given downshift ratio (FO/F) by using the Mellen and Moffett

curves and the appropriate formulae. In summary, we know

FO, LSP and A.

We find

LSS, FO/F, NDIS.

The Mellen and Moffett curves and the associate equations readily lend themselves to solving this problem because of the way the equations and the curves are set up.

The second problem is one of designing a parametric sonar starting from "scratch" where one only knows the desired, or the range of desired, LSS, F, and NDIS and wants to find FO, LSP and A. At first glance one would say, "Why not just work backwards through the equations with the aid of the Mellen and Moffett curves?" Alas, life is not so simple. The equations depend on a knowledge of FO, and A. In other words, something must be known about the projector before starting. Unfortunately, determining FO, A, and LSP is the goal of the design process. This is just the opposite of the analysis previously discussed. There is a method that has been proposed by Moffett that utilizes the "load line" technique previously mentioned. This method is excellent when an exact FO and A are sought for a given LSS, F, and NDIS. The method becomes time consuming and requires tedious repetitive calculations when a range of values is sought and when one needs numerous possibilities in order to examine and choose an optimum solution based on factors other than just parametric sonar considerations. What is needed is a method of constructing a matrix of possible parametric sonar designs for the designer to weigh in consort with associated system parameters. In summary for this situation we know

LSS, FO/F, NDIS

and we want to find

FO, LSP and A.

SOLUTION

The solution to the problem is computer aided design. A program was written that allows the designer to vary F, A, LSS, and FO/F in order to construct the desired design matrix. The program compilation is given in Appendix A. This program is versatile enough so that three other parameters temperature (T), salinity (S) and depth (D) can be varied in coarse steps and their effects on the design studied. The results are tabulated and two on-line plots are possible. The results of a sample example are shown in Appendix B. The on-line plots can be of any two variables and each plot can be altered by changing a computer card.

At present, one plot is acoustic power in dB (PADB) vs. FO/F for a given LSS with the parameters T, S, D, F and A held constant. Then either LSS, F, or A can be changed and another plot made. Thus, one can examine the range of possible designs that are within the desired power budget and select a reasonable one. The second plot is secondary directivity index (NDIS) vs FO/F for the same given conditions as in the previous plot. From this the designer can select the necessary quantities for a desired range of NDIS. Normally, many plots will be produced resulting in families of LSS curves with NDIS and PADB plotted against FO/F with T, S, D, constant for many combinations of F and A. Once a set of parameters is decided upon, the appropriate exact constants can be obtained from the tabulation.

One thing that has been done to aid in plot comparisons is to force the plots to a convenient common scale. This was done by the use of two dummy points on each plot. This was necessary because the routine as originally compiled by Gordon[3] automatically scaled the axis for the plotting range. For the desired comparisons of plots, such scaling is undesirable.

The program is outlined in a simplified flow chart shown in Figure 1. It operates as follows: The inner loop computes parametric sonar design constants for each of a sequence of FO/F values. This is done for each of a sequence of LSS values in the input data (LSS1). Next, the two inner loops are repeated for a sequence of values for A and finally these three innermost loops are repeated for each value of F in the input data. These four loops generate a matrix of possible designs for the ranges of FO/F, LSS, A, and F chosen. Each matrix is built up for constant values of T, S, and D. The values for T, S, and D can be altered by changing them when the data is programmed into the computer.

The plots as presently compiled plot after each sequence of FO/F for a given LSS. Thus, a family of curves of different LSS values is generated. These are for each combination of T, S, D, F, and A and are plotted with FO/F as the horizontal axis on each plot. The vertical axis on plot number 1 is PADB while the vertical axis on plot number 2 is NDIS.

A more detailed flow chart is shown in Figure 2. It shows an expansion of the computational block diagram of Figure 1. Thus, the location of the various calculations are shown along with the appropriate tests required to keep the program bounded. Once the data is entered, the calculations leading to the quantity 1/(2)(AL)(RO) are made where the attenuation loss is (AL) and the Rayleigh distance is (RO). This quantity 1/(2)(AL)(RO) together with the FO/F and a quantity X is entered into a numerical integration subroutine devised by Goldstein[4]. The X is a parameter that ties the integration to a scaled source level (L*) which is a normalized parametric quantity in the Mellen and Moffett theory. The output of the numerical integration enters into several simple computations, the results of which are tested to see if they fall within the

proper programmed bounds. If the tests are failed, a new value of X is chosen and the integration routine is redone and retested. Depending on how the tests are passed, the program either proceeds to calculate further parametric sonar quantities for the given solution of the numerical integration or the program recognizes that the numerical integration has searched as far as it can. In any event, the program will proceed to readout the results in a table then recycle to the next FO/F in the innermost loop. Once the desired LSS values has been completely investigated, the computer constructs the two on-line plots previously mentioned. The program then recycles until all possible values of F, A, LSS and FO/F have been investigated and all plots completed. The program then terminates. The detailed flow chart (Figure 2) references equations which are tabulated in Table I.

In essence, the program takes some known values for a given condition and hunts, by means of a numerical integration routine and specific tests, for other needed values to completely describe a parametric sonar. Since usually there is a range of desired values, the program builds a matrix of possible solutions. The accuracy of these solutions depends on the accuracy of the parameter X used in the numerical integration. Presently, the solution calculates an LSS which is compared with the input LSS (LSS1). The calculated value has a tolerance of $\pm$0.82 dB. The resultant LSP, parametric gain (G), acoustic power (PA and PADB), and primary frequency directivity index (NDIP) all have a tolerance of $\pm$0.41 dB. The NDIS has a $\pm$0.82 dB tolerance.

PROGRAM OPTIONS

The design program has certain options as a result of the general form in which it is written. The program contains four nested loops any of which can be varied or held constant by appropriate input data on the input data cards. The plots can be varied, however, this may involve repositioning the plot in the program as well as changing two program cards. The user may have to redimension the storage associated with the loops preceding the plot in order to be sure the data computed is retained until the plot is called.

Equation No.	Equation
1.	$X_{(I+1)} = 1.1X_I$ FOR 86 VALUES FROM $X = 0.090909$
2[5].	$FT = 21.9 \times 10^{6-(1520/(T+273))}$ kHz
3[5].	$AL = (1/8.68)(1/914.4)\left\{\left[(1.86\text{x}10^{-2})(S)(FT)(FO)^2/\left[(FT)^2+(FO)^2\right]\right] + \left[2.68\text{x}10^{-2}(FO)^2/FT\right] + \left[0.1(FO)^2/(1+(FO)^2)\right]\right\}(1-6.33233\text{x}10^5 D)$ NEPERS/METER
4[5].	$C = 1449.2 + 4.623T - 0.0546(T^2) + 1.391\ (S-35) + 0.017D$ METERS/SECOND
5[6].	$NDIP = 10\ LOG_{10}(4\pi A\ (FO)^2(10^3)^2/C^2)$ DB
6.	$PADB = LSP - 70.8 - NDIP$ DB
7.	$PA = ANTILOG\left[(1/10)(LSP-70.8-NDIP)\right]$ WATTS
8[1].	$NDIS = (NDIP) + 3 - 10\ LOG_{10}\left[1 + ((FO)/F)(2\pi(AL)(RO) + X)\right]$ DB

TABLE I

PROGRAM USAGE AND SAMPLE EXAMPLE

In order to use the program, the user must stack appropriately formatted data cards in a fixed order at the end of the program. There are six different types of cards. These cards will now be discussed in order from front to back of the stack.

The first type of card contains only one card and comes first in the data. It is formatted into 4 fields of one integer number per field. Each number must be right justified in a field width of five (Fortran V statement (I5)). The first field uses columns 1 through 5 and contains the number of F values. The second field uses columns 6 through 10 and contains the number of A values. The third field uses columns 11 through 15 and contains the number of LSS values. The fourth field uses columns 16 through 20 and contains the number of FO/F values plus 1. This arrangement of fields is summarized in Table 2.

The second type of card contains only one card and it is the 2nd card in the data. It is formatted into 3 fields. Each field contains a number that is written in a floating point format which is right justified in a field width of 10 with a 4 decimal place accuracy (Fortran V statement (F10.4)). The first field uses columns 1 through 10 and contains the value for T. The second field uses columns 11 through 20 and contains the value for 5. The third field uses columns 21 through 30 and contains the value for D. These fields are also summarized in Table 2.

The third through sixth type of cards may contain more than 1 card for each type but only one value for each card. Thus, one must use as many cards for each type as there are values associated with that type and the cards for each type must be grouped together. Each number is written in a floating point format which is right justified in a field width of 10 with a 5 decimal place accuracy (Fortran V statement (F10.5)). Each third type of card gives a value for F. Each fourth type of card gives a value for A. Each fifth type of card gives an input value for LSS (LSS1). Lastly, each sixth type of card gives a value for FO/F. Each of these field layouts are summarized in Table 2.

Card Type	Card Columns	Fortran IV Format	Agreement
1	1-5	I5	No. of F values
	6-10	I5	No. of A values
	11-15	I5	No. of LSS values
	16-20	I5	No. of FO/F values
2	1-10	F10.4	T in deg C
	11-20	F10.4	S in PPT
	21-30	F10.4	D in meters
3	1-10	F10.5	F in kHz
4	1-10	F10.5	A in sq. meters
5	1-10	F10.5	LSS in dB
6	1-10	F10.5	FO/F

TABLE 2

DATA CARD FORMATS

The use of this program requires the input of data from a program stored on tape in the NUSC New London Laboratory Univac 1108 files. This is tape U183. Different parameter plots may be made by simply changing the call to plot (Call Plot A) statements. There are two such plots in the program. The plot routine can be eliminated by removing the two call to plot cards which are located adjacent to each other in the program. The rest of the program should run and the table of results printed.

A sample example will now be discussed. Suppose we want to design a parametric sonar that has the following specifications:

$$LSS = 90 \text{ dB//1}\mu\text{bar-meter}$$

$$F = 3 \text{ kHz}$$

$$N_{DI} = 30 \text{ dB to } 35 \text{ dB}$$

and the power budget is such that we wish to minimize its consumption. Assume that the system will work in the ocean (S = 35 ppt) and that the system must be capable of operating in the winter (T = 7°C) on the surface (D = 0). The data is programmed as shown in Figure 3. The tables of results are shown in Appendix B along with 3 sets of plots. Examination of the results shows several design possibilities all within the region of a dip in the PADB plots. If it were not possible to examine so large a quantity of points, the dip quite possibly would go unnoticed because there is a tendency for the unwitting designer to assumethat increased stepdown ratio means increased power consumption. Apparently, this is not always true. When the desired points are isolated on the plots, the designer then can go to the tables and from them he can determine the design that gives the desired source level within the NDIS restrictions. The desired design for the sample example is the one underlined in the appropriate table of Appendix B and encircled on each of the associated PADB and NDIS vs FO/F plots. The selected design has the following parameters:

$$FO/F = 10$$

$$FO = 30 \text{ kHz}$$

$$LSP = 131.2 \text{ dB//1}\mu\text{bar-meter}$$

$$NDIP = 36.1 \text{ dB}$$

$$NDIS = 34.4 \text{ dB}$$

and $PA = 267.1$ watts/each primary frequency.

Other related quantities can be obtained from the data tables. For different applications these quantities may assume importance and thus are readily available if design tradeoffs become necessary.

CONCLUSION

A computer aided parametric sonar design program has been written for the UNIVAC 1108. This program allows the designer to take a given secondary source level (LSS), secondary frequency (F) and secondary directivity index (NDIS) and compute a range of possible parametric sonar designs that will satisfy his needs. Thus, the selection of sonar parameters is no longer limited by the difficulty of examining a range of possible parametric designs. The sonar designer can now construct a matrix of possible designs then base the final selection on which of these designs best fits the other systems parameters being considered. By means of computer aided design, literally hundreds of possible designs for a given situation can be investigated in a short time.

REFERENCES

1. Mellen, R. H. and M. B. Moffett, "A Model for Parametric Radiator Design," USN Journal of Underwater Acoustics, Vol. 22, No. 2, April 1972 (Unclassified).

2. Moffett, M. B., "Load Line Technique for Parametric Design," unpublished communication in 1972.

3. Gordon, R. L., "A Fortran V Plotting Routine for the Univac 1108 High Speed Printers," USL Tech Memo No. 2242-291-68, 25 July 1968 (Unclassified).

4. Goldstein, M., "On A numerical Integration in Parametric Sonar Research," NUSC Tech Memo No. PA4-268-71, 21 Oct 1971, (Unclassified).

5. Urick, R. J., "Principles of Underwater Sound for Engineers," McGraw Hill, Copyright 167, pages 88-96.

6. "The Design and Construction of Magnetostriction Transducers," NDRC Div 6 Report Vol. 13, dated 1946, p. 128.

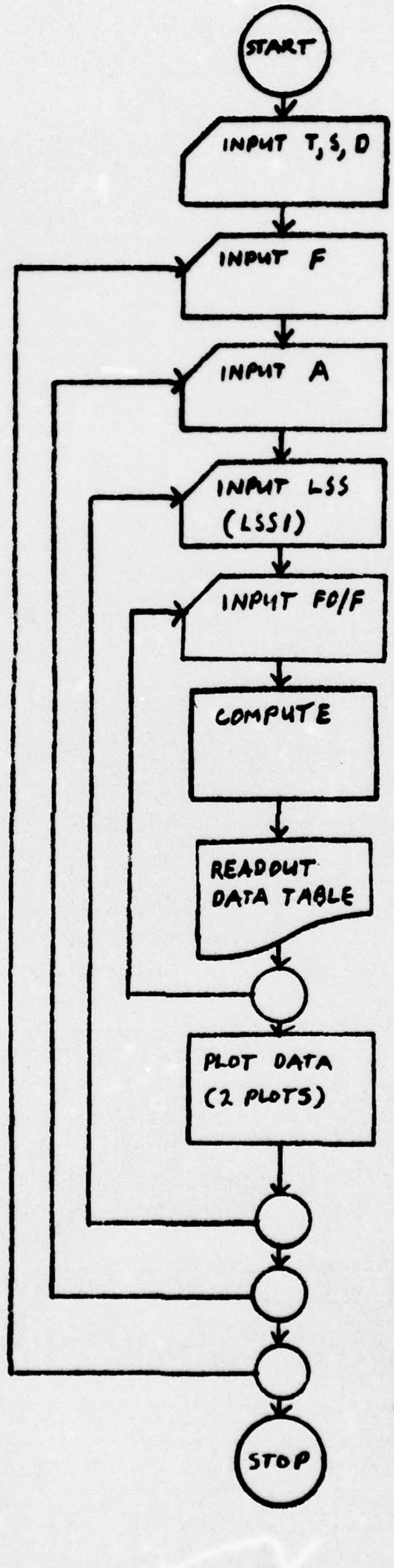
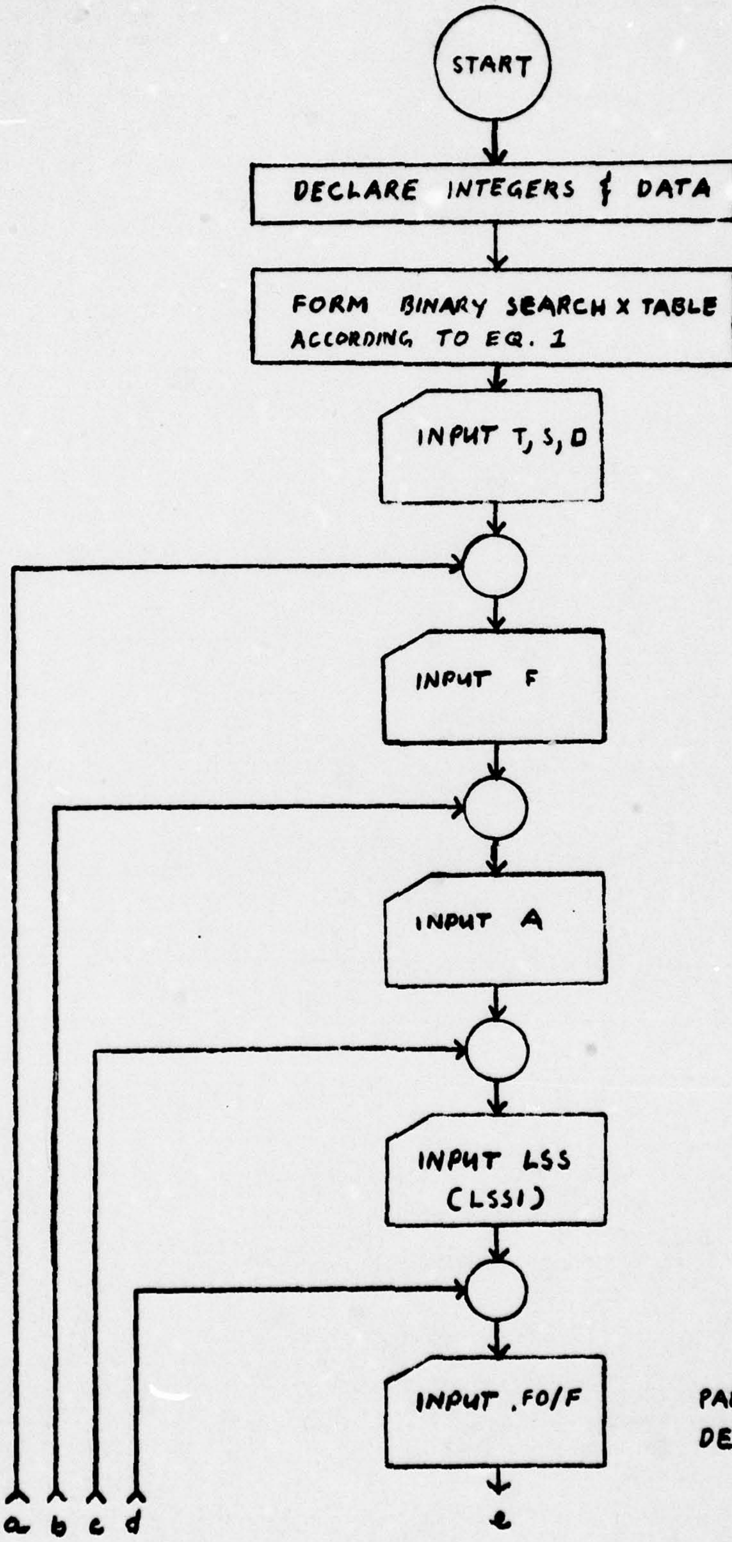


FIGURE 1

PARAMETRIC SONAR DESIGN, SIMPLIFIED FLOW CHART



NOTE:
FOR EQUATIONS SEE TABLE 1

FIGURE 2

PARAMETRIC SONAR DESIGN, DETAILED FLOW CHART

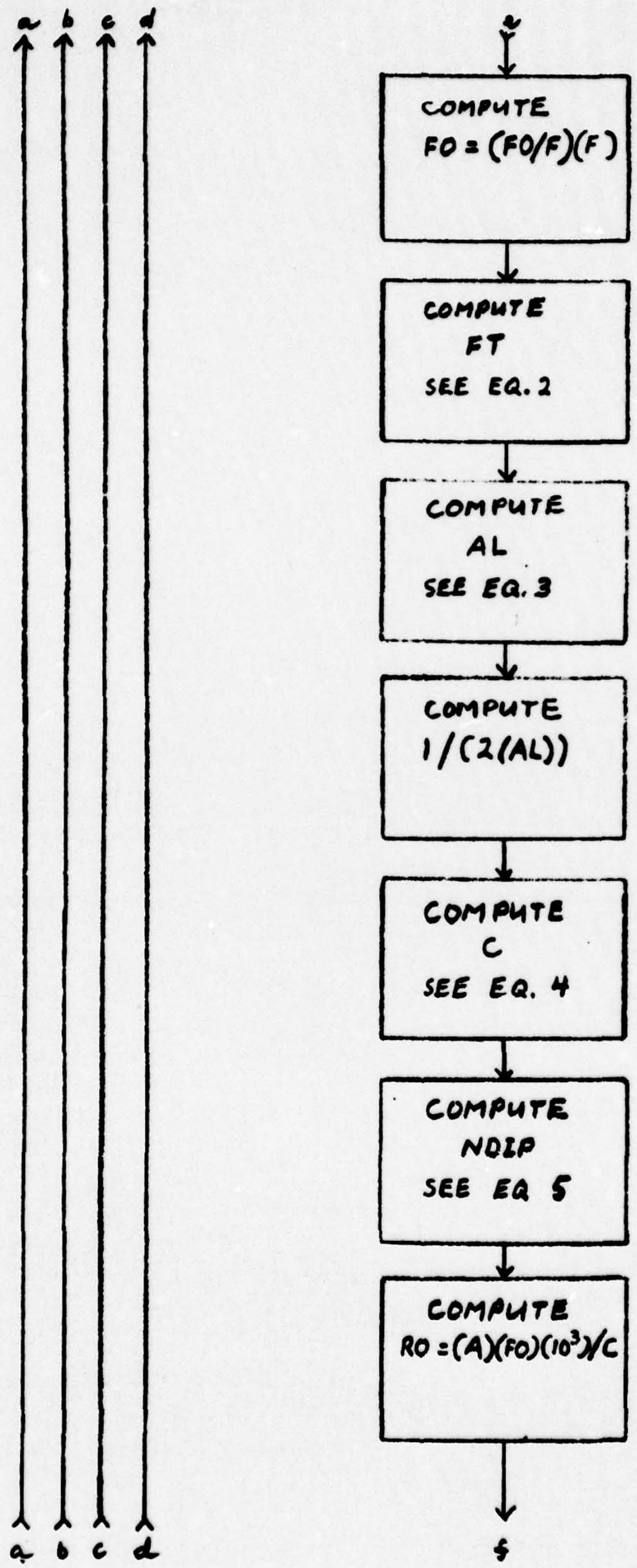


FIGURE 2 (CONT. 1)

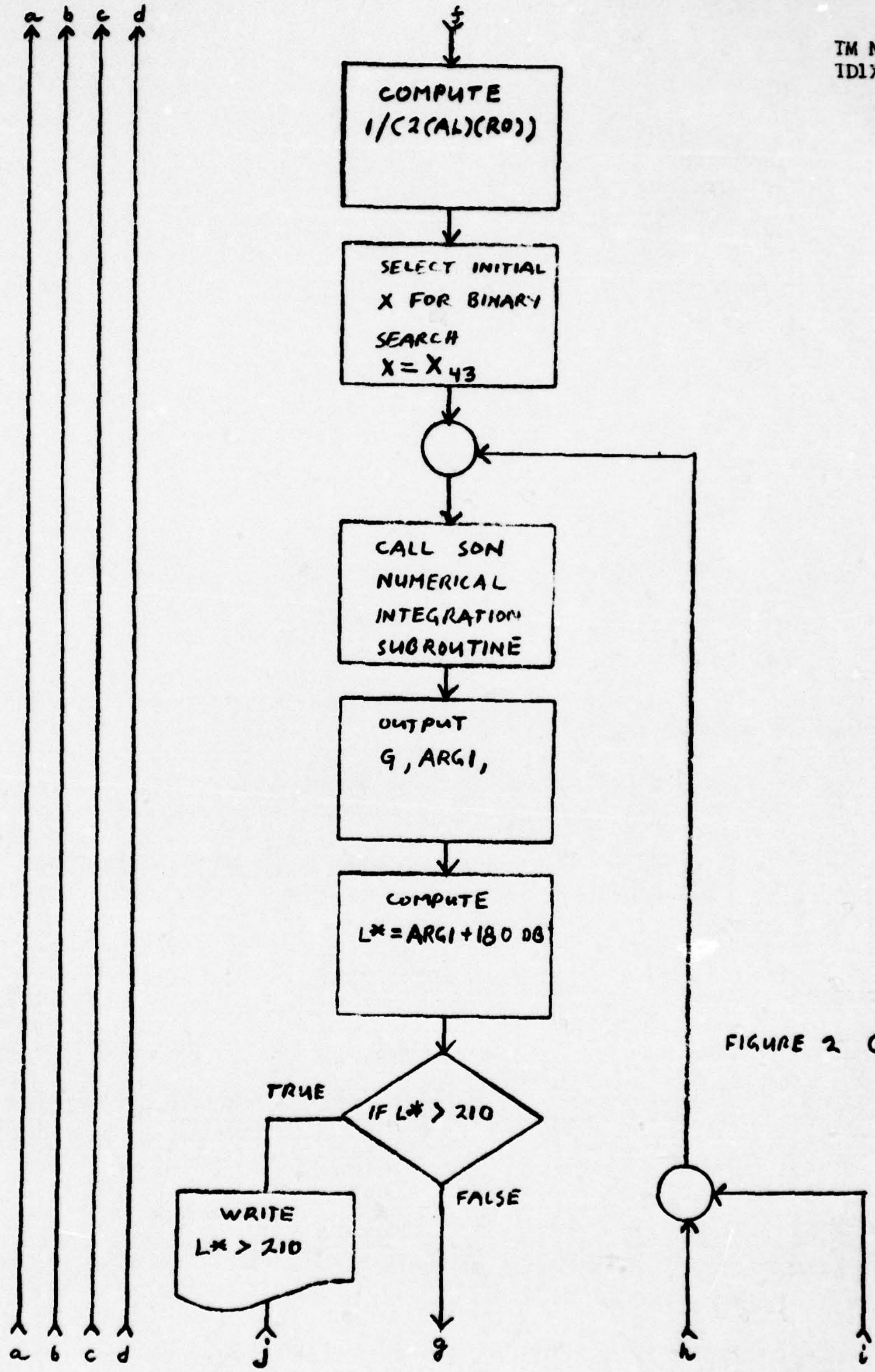


FIGURE 2 (CON'T 2)

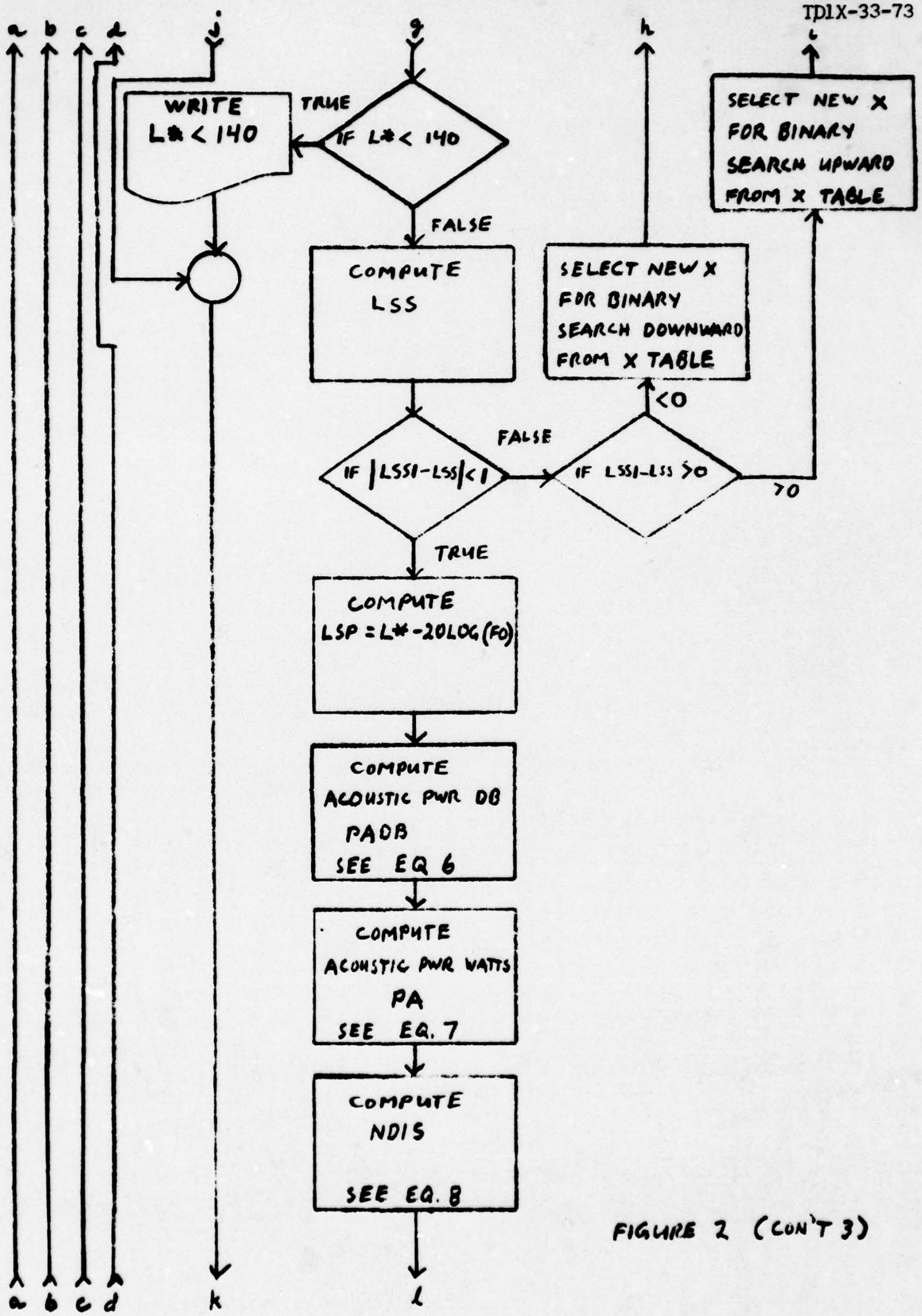


FIGURE 2 (CON'T 3)

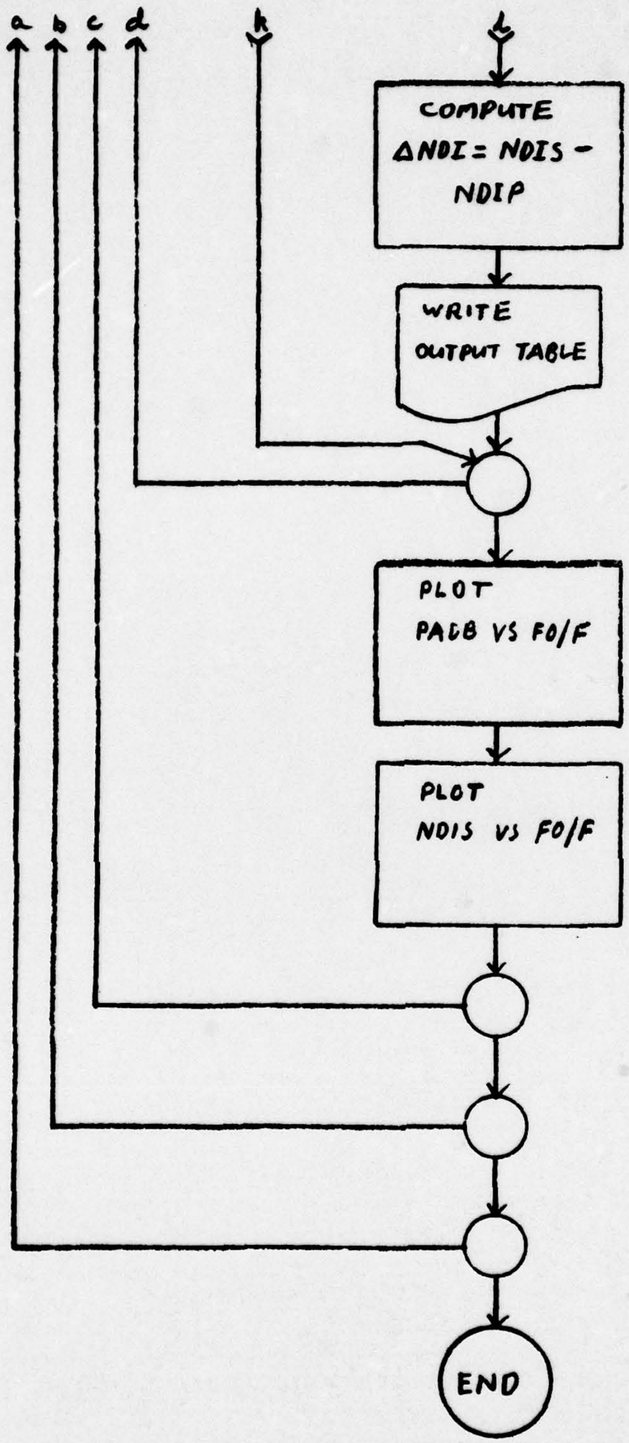


FIGURE 2 (CON'T. 4)

COLUMN NUMBER

	1–5	6–10	11–15	16–20	21–25	26–30
CARD 1	1	3	1	12		
CARD 2		7.		35.		0.
TYPE 3 CARDS		3.				
TYPE 4 CARDS		.1964				
		.3927				
		.7854				
TYPE 5 CARDS		90.				
TYPE 6 CARDS		5.				
		7.5				
		10.				
		12.5				
		15.				
		20.				
		30.				
		40.				
		50.				
		70.				
		100.				

FIGURE 3

SAMPLE EXAMPLE DATA FORMAT

APPENDIX A

PROGRAM COMPILATION

The program compilation shown here is complete with subroutines except for the plot subroutine. That particular one was on tape and was not compiled as was the material that was put in by means of a deck of cards.

```
FOR SUB,SUB                                                                                  21:34:46. 50
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:46

   SUBROUTINE SUB       ENTRY POINT 000067

   STORAGE USED: CODE(1) 000103; DATA(0) 000020; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003  BLK    000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   DSINH
    0005   DEXP
    0006   DSQRT
    0007   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0003 D 000000 ARO      0003 D 000006 E        0003 D 000002 GKDKO      0000   000012 INJPS     0000 D 000000 T
    0003 D 000004 X


00101      1*        SUBROUTINE SUB(A,J,H,F)
00103      2*        IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00104      3*        COMMON/BLK/ARO,GKDKO,X,E
00105      4*        T=A+J*H
00106      5*        F=DSINH(T)
00107      6*        T=1.0D0+((X*T)**2)/4.0D0
00110      7*        IF(ARO.GT.0.0D0) E=DEXP(-F*ARO)
00112      8*        F=F**2
00113      9*        F=(1.0D0+F)/(1.0D0+F*GKDKO**2)
00114     10*        F=E*(DSQRT(F)/T)
00115     11*        RETURN
00116     12*        END

     END OF COMPILATION:       NO  DIAGNOSTICS.
```

```
FOR ROM,ROM                                                                      21:34:47. 40
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:47

   SUBROUTINE ROM        ENTRY POINT 000246

   STORAGE USED: CODE(1) 000275; DATA(0) 000060; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003    SUB
    0004    NEXP1$
    0005    NEXP4$
    0006    NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000071 1206      0001    000120 1306     0001    000033 4L       0000 D 000003 F       0000 D 000005 FN
    0000 D 000000 H           0000    000031 INJP$    0000 I 000015 IU        0000 I 000012 J       0000 I 000013 J1
    0000 I 000002 K           0000 I 000014 L         0000 I 000011 M         0000 D 000007 SIG

00101            SUBROUTINE ROM(A,B,W,EPS,IV,NMX)
00103            DIMENSION W(NMX,NMX)
00104            IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00105            H=B-A
00106            K=0
00107            CALL SUB(A,0,H,F)
00110            FN=F
00111            CALL SUB(A,1,H,F)
00112            W(1,1)=((F+FN)*H)/2.0D0
00113          4 K=K+1
00114            H=H/2.0D0
00115            SIG=0.0D0
00116            M=2**(K-1)
00117            DO 1 J=1,M
00122            J1=2*J-1
00123            CALL SUB(A,J1,H,F)
00124          1 SIG=SIG+F
00126            W(K+1,1)=W(K,1)/2.0D0+H*SIG
00127            DO 2 L=1,K
00132            IU=K+1-L
00133            IV=L+1
00134          2 W(IU,IV)=(4.0D0**(IV-1)*W(IU+1,IV-1)-W(IU,IV-1))/(4.0D0**(IV-1)-1.
00134           1D0)
00136            IF(ABS(W(IU,IV)-W(IU,IV-1)).LT.ABS(W(IU,IV))*EPS) RETURN
00140            GO TO 4
00141            END

   END OF COMPILATION:        NO DIAGNOSTICS.
```

```
    FOR SON,SON                                                                                       21:34:48.364
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:48

   SUBROUTINE SON        ENTRY POINT 000134

   STORAGE USED: CODE(1) 000160; DATA(0) 011664; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   BLK     000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   ROM
    0005   DLOG
    0006   DATAN
    0007   DLOG10
    0010   NERR3S

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000045 1L       0000 D 011612 A       0000 D 011620 ALN1     0003 D 000000 ARO      0000 D 011614 B
    0003 D 000006 E        0000 D 011610 EPS     0000 D 011622 FAC      0003 D 000002 GKDKO    0000 D 011616 GKDKOS
    0000   011650 INJPS    0000 I 011624 IV      0000 D 000000 W        0003 D 000004 X

 00101      1*            SUBROUTINE SON (RARO,RKDKO,ARG,ANS,AIN,NMX)
 00103      2*            IMPLICIT DOUBLE PRECISION (A-H,O-Z)
 00104      3*            COMMON/BLK/ARO,GKDKO,X,E
 00105      4*            DIMENSION W(50,50)
 00106      5*            EPS=.5D-05
 00107      6*            A=0.0
 00110      7*            B=20.0
 00111      8*            E=1.CD0
 00112      9*            ARO=0.0D0
 00113     10*            IF(RARO.GT.ARO) ARO=1.0D0/RARO
 00115     11*            GKDKO=1.0D0/RKDKO
 00116     12*            GKDKOS=GKDKO**2
 00117   *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00117     13*            IF(RARO.EQ.0.0D0) GO TO 1
 00121     14*            ALN1=DLOG(RKDKO)
 00122     15*            B=DLOG((84.0D0+ALN1)*RARO)
 00123     16*          1 FAC=GKDKOS*(X/2.0D0)
 00124     17*            CALL ROM(A,B,W,EPS,IV,50)
 00125     18*            AIN=W(1,IV)
 00126   *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00126     19*            IF(RARO.EQ.0.0D0) AIN=AIN+2.0D0*RKDKO*(1.5707963267948900-DATAN(10
 00126     20*           1.0D0*X))/X
 00130     21*            AIN=FAC*AIN
 00131     22*            ARG=20.0D0*DLOG10(X)
 00132     23*            ANS=20.0D0*DLOG10(AIN)
```

```
00133      24*        RETURN
00134      25*        END

      END OF COMPILATION:        2 DIAGNOSTICS.
```

```
@     FOR SONAR,SONAR                                                                              21:34:49.464
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:49

    MAIN PROGRAM

    STORAGE USED: CODE(1) 001012; DATA(0) 004536; BLANK COMMON(2) 000000

     COMMON BLOCKS:

     0003    BLK     000010

    EXTERNAL REFERENCES (BLOCK, NAME)

     0004    SON
     0005    PLOTA
     0006    NRDU$
     0007    NI02$
     0010    NEXP0$
     0011    NI01$
     0012    NWDU$
     0013    ALOG10
     0014    DLOG10
     0015    NSTOP$

    STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0000   004023 100F     0000   004002 101F     0000   004003 102F     0000   004025 103F     0000   004242 104F
     0000   004262 105F     0000   004321 106F     0000   004346 107F     0000   004356 112F     0000   004402 113F
     0000   004426 114F     0001   000016 117G     0001   000523 13L      0001   000531 14L      0001   000541 15L
     0001   000140 156G     0001   000160 164G     0001   000557 17L      0001   000172 172G     0001   000204 200G
     0001   000573 200L     0001   000234 206G     0001   000671 210L     0001   000237 211G     0001   000247 214G
     0001   000717 220L     0001   000312 236G     0001   000430 257G     0001   000744 4L       0001   000571 5L
     0000 R 001130 A        0000 R 002424 ADUM     0000 D 003410 AIN      0000 R 001750 ALPHA    0000 D 003416 ANS
     0000 R 003244 ANS1     0000 D 003414 ARG      0000 R 003100 ARG1     0003 D 000000 ARO      0000 R 003760 C
     0000 R 003753 D        0000 R 001274 DELNDI   0000 R 004000 DUM      0003 D 000006 E        0000 R 000764 F
     0000 R 001440 FO       0000 R 003764 FT       0003 D 000002 GKDKO    0000 I 003737 I        0000 I 003754 IA
     0000 I 003755 IB       0000 I 003756 IC       0000 I 003734 ICARD    0000 I 003774 ICONST   0000 I 003757 ID
     0000 I 003776 IDUM1    0000 I 003775 IDUM2    0000 I 003761 II       0000 I 003773 IIX      0000 I 003767 IMAX
     0000 I 003770 IMID     0000 I 003766 IMIN     0000 I 003771 IND      0000 I 003772 IOPT     0000 I 003735 IPRINT
     0000 I 003777 ISAVE    0000 I 003762 J        0000 I 003763 JJ       0000 I 003740 KN       0000 I 003741 KN1
     0000 I 003742 KN2      0000 I 003743 KN3      0000 R 000620 LSP      0000 R 000000 LSS      0000 R 000144 LSS1
     0000 I 003744 N        0000 R 000454 NDIP     0000 R 000310 NDIS     0000 I 003765 NLX      0000 I 003745 N1
     0000 I 003746 N2       0000 I 003747 N3       0000 I 003750 N4       0000 R 002114 PA       0000 R 002260 PADB
     0000 R 003736 PI       0000 R 004001 PY       0000 R 002570 RARO     0000 D 003420 RARO1    0000 R 002734 RFDFO
     0000 D 003422 RFDFO1   0000 R 001604 RO       0000 R 003752 S        0000 R 003751 T        0003 D 000004 X
     0000 D 003412 XO       0000 D 003424 XX

00101      1*          REAL LSS,LSS1,NDIS,NDIP,LSP
00103      2*          PARAMETER LMX=100
00104      3*          DIMENSION LSS(LMX),LSP(LMX),LSS1(LMX),NDIS(LMX),F(LMX),A(LMX)
00105      4*          DIMENSION DELNDI(LMX),FO(LMX),RO(LMX),ALPHA(LMX),NDIP(LMX),PA(LMX)
00106.     5*          DIMENSION PADB(LMX),ADUM(LMX),RARO(LMX),RFDFO(LMX),ARG1(LMX),ANS1(
```

```
      1LMX)
      DOUBLE PRECISION ARO,GKDKO,X,E,AIN,XO,ARG,ANS,RARO1,RFDFO1
      DOUBLE PRECISION XX(LMX)
      COMMON/BLK/ARO,GKDKO,X,E
      ICARD=3
      IPRINT=4
      PI=3.14159
C
C        CARD   COLUMNS   FORMAT   ARGUMENT
C        ----   -------   ------   --------
C          1      1-5       I5       KN- NO. OF F VALUES
C                 6-10      I5       KN1- NO. OF A VALUES
C                 11-15     I5       KN2- NO. OF LSS VALUES
C                 16-20     I5       KN3- NO. OF FO/F VALUES +1
C          2      1-10      F10.4    T
C                 11-20     F10.4    S
C                 21-30     F10.4    D
C        IN THE FOLLOWING CARDS,IF MORE THAN ONE VALUE OF THE VARIABLES
C        IS DESIRED (BASED ON CARD NO.1) THEN RELATED CARDS (ALL F'S) MUST
C        BE GROUPED TOGETHER
C          3      1-10      F10.5    F
C          4      1-10      F10.5    A
C          5      1-10      F10.5    LSS
C          6      1-10      F10.5    FO/F
C
      XO=.90909091D-2
      DO 8 I=1,86
      XX(I)=1.1*XO
    8 XO=XX(I)
      READ(ICARD,101) KN,KN1,KN2,KN3
  101 FORMAT(4I5)
      N=KN
      N1=KN1
      N2=KN2
      N3=KN3
      N4=N3+1
      RFDFO(1)=0.0
      PADB(1)=0.0
      NDIS(1)=0.0
C
C        IF POWER IS IN EXCESS OF 100KW CHANGE SCALE OF PADB PLOT
C
      PADB(N4)=50.
      NDIS(N4)=50.
      RFDFO(N4)=0.0
      READ(ICARD,102) T,S,D
  102 FORMAT(3F10.4)
      READ(ICARD,100) (F(IA),IA=1,N)
      READ(ICARD,100) (A(IB),IB=1,N1)
      READ(ICARD,100) (LSS1(IC),IC=1,N2)
      READ(ICARD,100) (RFDFO(ID),ID=2,N3)
      C=1449.2+4.623*T-.0546*(T**2)+1.391*(S-35.)+.017 *D
      DO 1 I=1,KN
      DO 2 II=1,KN1
      DO 3 J=1,KN2
      WRITE(IPRINT,107)
      WRITE(IPRINT,103)
      WRITE(IPRINT,114)
```

```
      WRITE(IPRINT,104) T,D,S,C,A(II)
      WRITE(IPRINT,105)
      DO 4 JJ=2,KN3
      FO(JJ)=RFDFO(JJ)*F(I)
      E=(10.**3)*FO(JJ)
      FT=21.9*10.**(6.-(1520./(T+273.)))
      ALPHA(JJ)=(1./8.68)*(1.-(.00006332*D))*(1./914.4)*(.0186*((S*FT*(F
     1O(JJ)**2))/(FT**2+FO(JJ)**2))+(.0268*FO(JJ)**2/FT   )+((.1*FO(JJ)*
     2*2)/(1.+FO(JJ)**2)))
      NDIP(JJ)=10.*ALOG10((4.*PI*A(II)*E**2)/C**2)
      RO(JJ)=(A(II)*FO(JJ)*(10.**3))/C
      RAHO(JJ)=1.0/(2.*ALPHA(JJ)*RO(JJ))
      ADUM(JJ)=1.0/(2.*ALPHA(JJ))
      NLX=86
      IMIN=1
      IMAX=NLX
      IMID=NLX/2
      IND=NLX/2
      IOPT=0
   20 DO 5 IIX=1,91
      X=AX(IND)
      RAHO1=RAHO(JJ)
      RFDFO1=RFDFO(JJ)
      CALL SUN(RAHO1,RFDFO1,ARG,ANS,AIN,50)
      ARG1(JJ)=ARG
      ANS1(JJ)=ANS
      ARG1(JJ)=ARG1(JJ)+180.
      IF(ARG1(JJ).GT.210.) GO TO 210
      IF(ARG1(JJ).LT.140.) GO TO 220
      LSS(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))+ANS1(JJ)
      IF(ABS(LSS1(J)-LSS(JJ)).LT.1.) GO TO 200
      IF(IOPT.NE.0) GO TO 15
      IOPT=1
      IF(LSS1(J)-LSS(JJ)) 12,12,13
   12 ICONST=-1
      IDUM2=IMIN
      IDUM1=IMID
      GO TO 14
   13 ICONST=1
      IDUM1=IMAX
      IDUM2=IMID
   14 IND=(IDUM1+IDUM2+ICONST)/2
      ISAVE=IDUM2
      GO TO 5
   15 IF(LSS1(J)-LSS(JJ)) 17,17,16
   16 ICONST=1
      ISAVE=IND
      IDUM2=IND
      IND=(IDUM1+IDUM2+ICONST)/2
      GO TO 5
   17 ICONST=-1
      IDUM2=ISAVE
      IDUM1=IND
      IND=(IDUM1+IDUM2+ICONST)/2
    5 CONTINUE
  200 LSP(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))
      PADB(JJ)=LSP(JJ)-70.8-NDIP(JJ)
      DUM=.1*PADB(JJ)
```

```
00340        PA(JJ)=10.**DUM
00341        NDIS(JJ)=(NDIP(JJ)+3.)-10.*ALOG10(1.+(RFDFO(JJ)*(2.*PI*ALPHA(JJ)*R
00341       1O(JJ)+X)))
00342        DELNDI(JJ)=NDIS(JJ)-NDIP(JJ)
00343        WRITE(IPRINT,106)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00343       1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ),PA(J
00343       2J),NDIS(JJ),DELNDI(JJ)
00365        GO TO 4
00366    210 LSP(JJ)=0.0
00367        PADB(JJ)=0.0
00370        NDIS(JJ)=0.0
00371        WRITE(IPRINT,112)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00371       1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00410        GO TO 4
00411    220 LSP(JJ)=0.0
00412        PADB(JJ)=0.0
00413        NDIS(JJ)=0.0
00414        WRITE(IPRINT,113)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00414       1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00433      4 CONTINUE
00433  C
00433  C     THE PLOT ROUTINES ARE ON TAPE U183
00433  C
00435        CALL PLOTA(RFDFO,PADB,PY,N4,1H*,1H+,1,'PADB VS FO/F',2,IPRINT)
00436        CALL PLOTA(RFDFO,NDIS,PY,N4,1H*,1H+,1,'NDIS VS FO/F',2,IPRINT)
00437      3 CONTINUE
00441      2 CONTINUE
00443      1 CONTINUE
00445    100 FORMAT(F10.5)
00446    103 FORMAT(50X,'T= WATER TEMPERATURE (DEGREES C)'
00446       1,//50X,'D= PROJECTOR DEPTH (METERS)',
00446       3//50X,'S= SALINITY (PPT)',
00446       4//50X,'F= SECONDARY FREQUENCY (KHZ)',
00446       5//50X,'A= PROJECTOR AREA (SQ. METERS)',
00446       6//50X,'FO/F= DOWNSHIFT RATIO',
00446       7//50X,'FO= PRIMARY FREQUENCY (KHZ)',
00446       8//50X,'AL= ABSORPTION CONSTANT (NEPERS/METER)',
00446       9//50X,'1/2AL= REACTION LIMIT (METERS)',
00446       1//50X,'RO= RAYLIEGH DISTANCE (METERS)',
00446       2//50X,'NDIP= DIRECTIVITY INDEX-PRIMARY (DB)',
00446       3//50X,'LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)',
00446       4//50X,'LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)',
00446       5//50X,'L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)',
00446       6//50X,'G= PARAMETER GAIN (DB)',
00446       7//50X,'PA= ACOUSTIC POWER PER TONE (WATTS)',
00446       8//50X,'ANDI= DIRECTIVITY GAIN (DB)',
00446       9//50X,'NDIS= SECONDARY DIRECTIVITY INDEX (DB)',
00446       1//50X,'PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE')
00447    104 FORMAT(//5X,'T= ',F5.0,//5X,'D= ',F8.1,//5X,'S= ',F4.0,//5X,'C= ',
00447       1F8.0,//5X,'A= ',F9.4)
00450    105 FORMAT(5X,'F',8X,'PADB',3X,'FO/F',5X,'FO',8X,'AL',5X,'1/2AL',5X,'R
00450       1O',4X,'1/2ALRO',1X,'NDIP',3X,'LSS',4X,'LSP',4X,'L*',5X,'G',5X,'PA(
00450       2WATTS)',1X,'NDIS',3X,'ANDI')
00451    106 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00451       11,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,1X,F9.1,1X,F5.1,2X,F5.1)
00452    107 FORMAT(49X,'PARAMETRIC SONAR DESIGN AND ANALYSIS')
00453    112 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00453       11,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* > 210.')
```

```
00434     180*       113 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00454     181*          1,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* < 140.')
00455     182*       114 FORMAT(1H1)
00456     183*           STOP
00457     184*           END

          END OF COMPILATION:        NO  DIAGNOSTICS.
```

APPENDIX B

SAMPLE EXAMPLE READOUT

The sample example tables and plots are shown here. These are as they appear on line out of the high speed printer associated with the computer.

```
PARAMETRIC SONAR DESIGN AND ANALYSIS
 T= WATER TEMPERATURE (DEGREES C)

 D= PROJECTOR DEPTH (METERS)

 S= SALINITY (PPT)

 F= SECONDARY FREQUENCY (KHZ)

 A= PROJECTOR AREA (SQ. METERS)

 FO/F= DOWNSHIFT RATIO

 FO= PRIMARY FREQUENCY (KHZ)

 AL= ABSORPTION CONSTANT (NEPERS/METER)

 1/2AL= REACTION LIMIT (METERS)

 RO= RAYLIEGH DISTANCE (METERS)

 NDIP= DIRECTIVITY INDEX-PRIMARY (DB)

 LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)

 LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)

 L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)

 G= PARAMETER GAIN (DB)

 PA= ACOUSTIC POWER PER TONE (WATTS)

 ANDI= DIRECTIVITY GAIN (DB)

 NDIS= SECONDARY DIRECTIVITY INDEX (DB)

 PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE
```

T= 7.

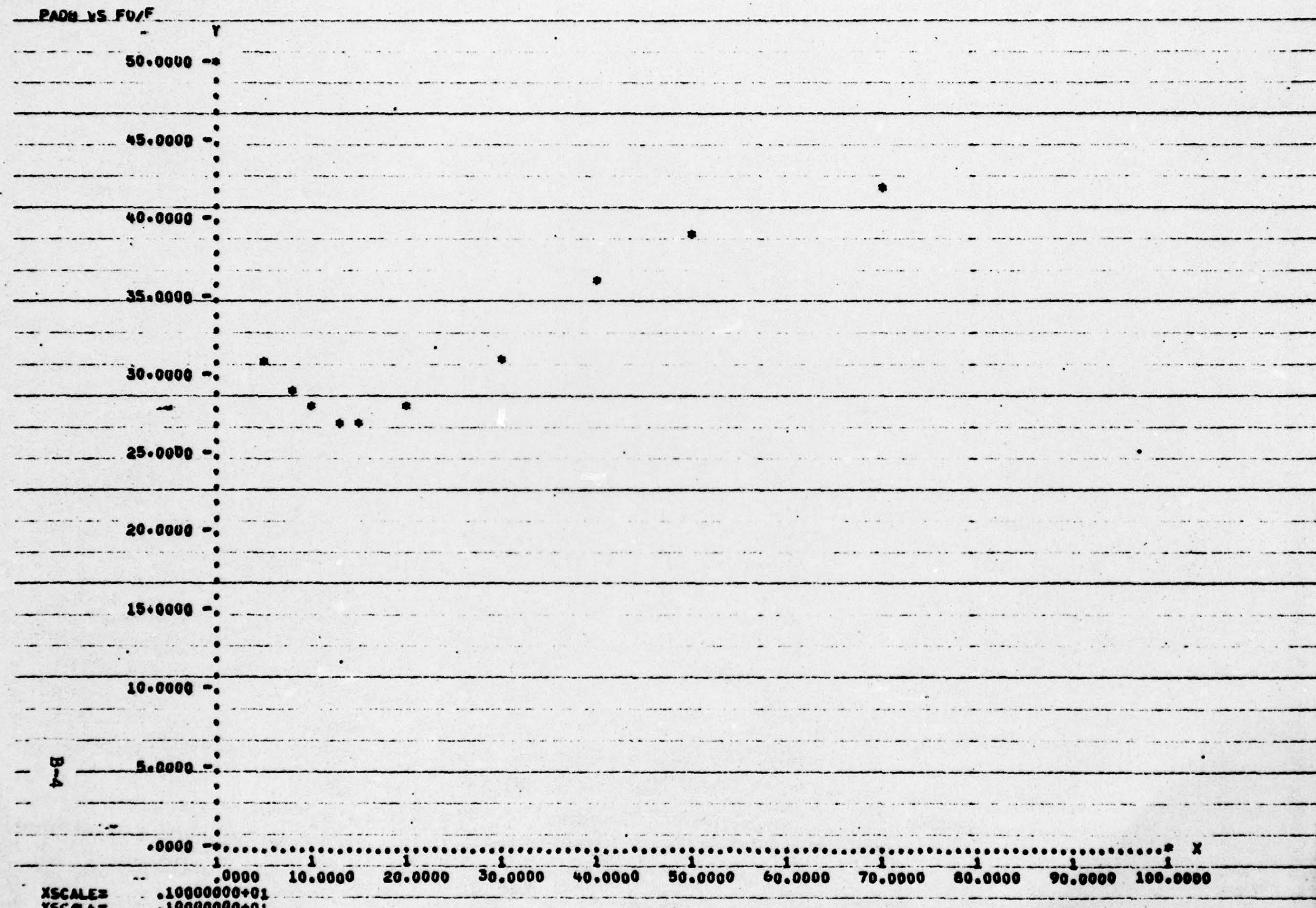
D= .0

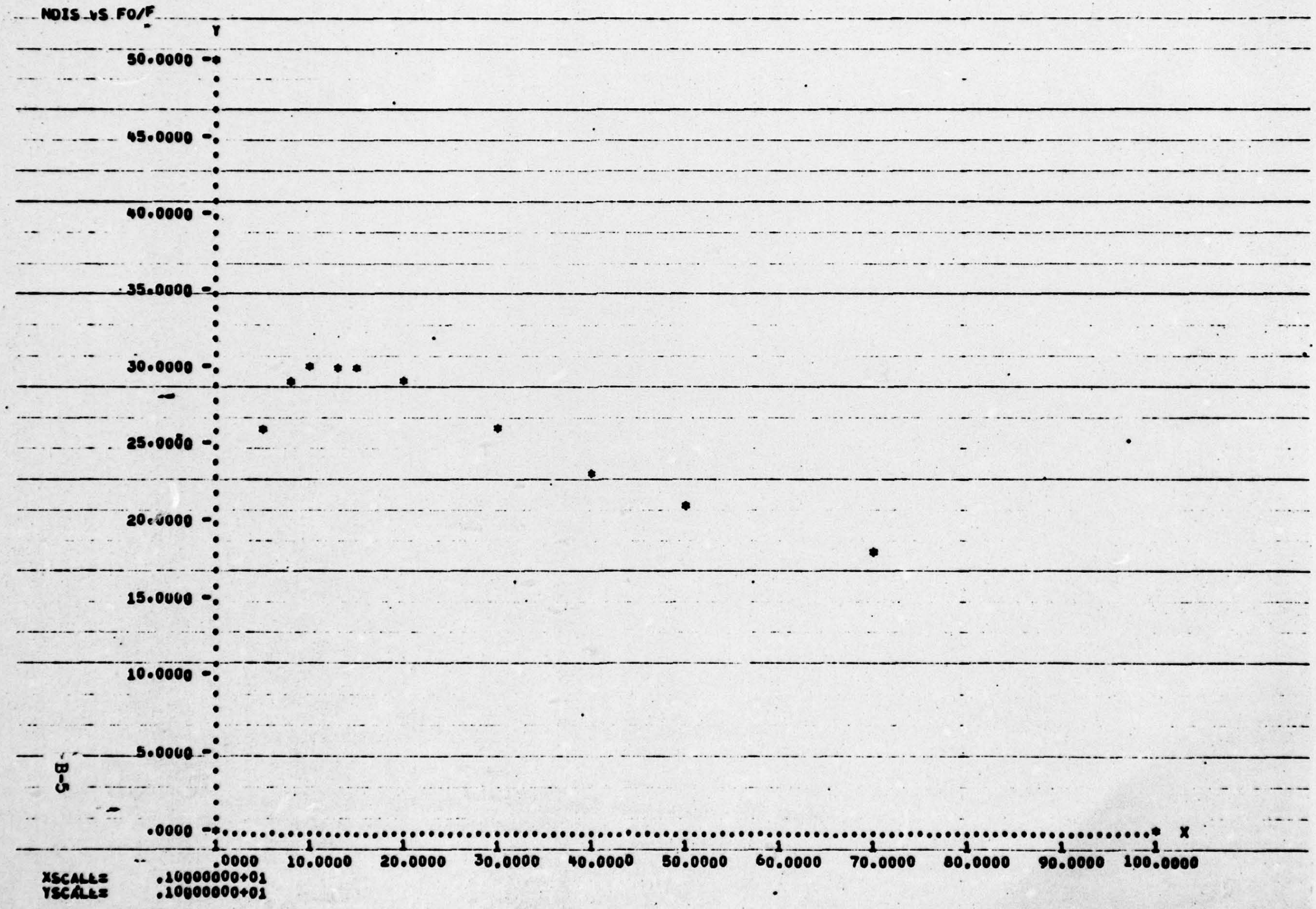
S= 35.

C= 1479.

A= .1960

F	PADB	FO/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	θ	PA(WATTS)	NDIS	ΔNDI
3.000	30.7	5.00	15.000	.000241	2079.	2.	1043.5	24.0	89.4	125.6	149.1	-36.2	1185.2	26.4	2.4
3.000	29.5	7.50	22.500	.000506	988.	3.	330.5	27.6	91.0	127.9	154.9	-36.9	889.0	28.8	1.3
3.000	27.8	10.00	30.000	.000846	591.	4.	148.3	30.1	89.8	128.7	158.2	-38.9	603.0	30.0	-.1
3.000	27.2	12.50	37.500	.001257	404.	5.	81.1	32.0	89.7	130.0	161.5	-40.3	529.4	30.3	-1.7
3.000	27.4	15.00	45.000	.001657	302.	6.	50.5	33.6	90.2	131.8	164.8	-41.5	547.3	30.0	-3.6
3.000	28.2	20.00	60.000	.002510	199.	8.	25.0	36.1	90.5	135.1	170.6	-44.6	657.6	29.0	-7.1
3.000	31.1	30.00	90.000	.004021	124.	12.	10.4	39.6	89.2	141.5	180.6	-52.3	1279.5	26.4	-13.2
3.000	36.0	40.00	120.000	.005186	96.	16.	6.1	42.1	89.5	148.9	190.5	-59.4	3987.5	23.2	-18.9
3.000	38.8	50.00	150.000	.006109	82.	20.	4.1	44.0	89.4	153.6	197.1	-64.2	7504.9	21.0	-23.0
3.000	42.0	70.00	210.000	.007653	65.	28.	2.3	47.0	89.3	159.8	206.2	-70.5	15902.7	18.1	-28.8
3.000	.0	100.00	300.000	.009969	50.	40.	1.3	50.1	83.0	.0	210.4	-76.9	L* > 210.		


PADH VS FD/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01


NDIS VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

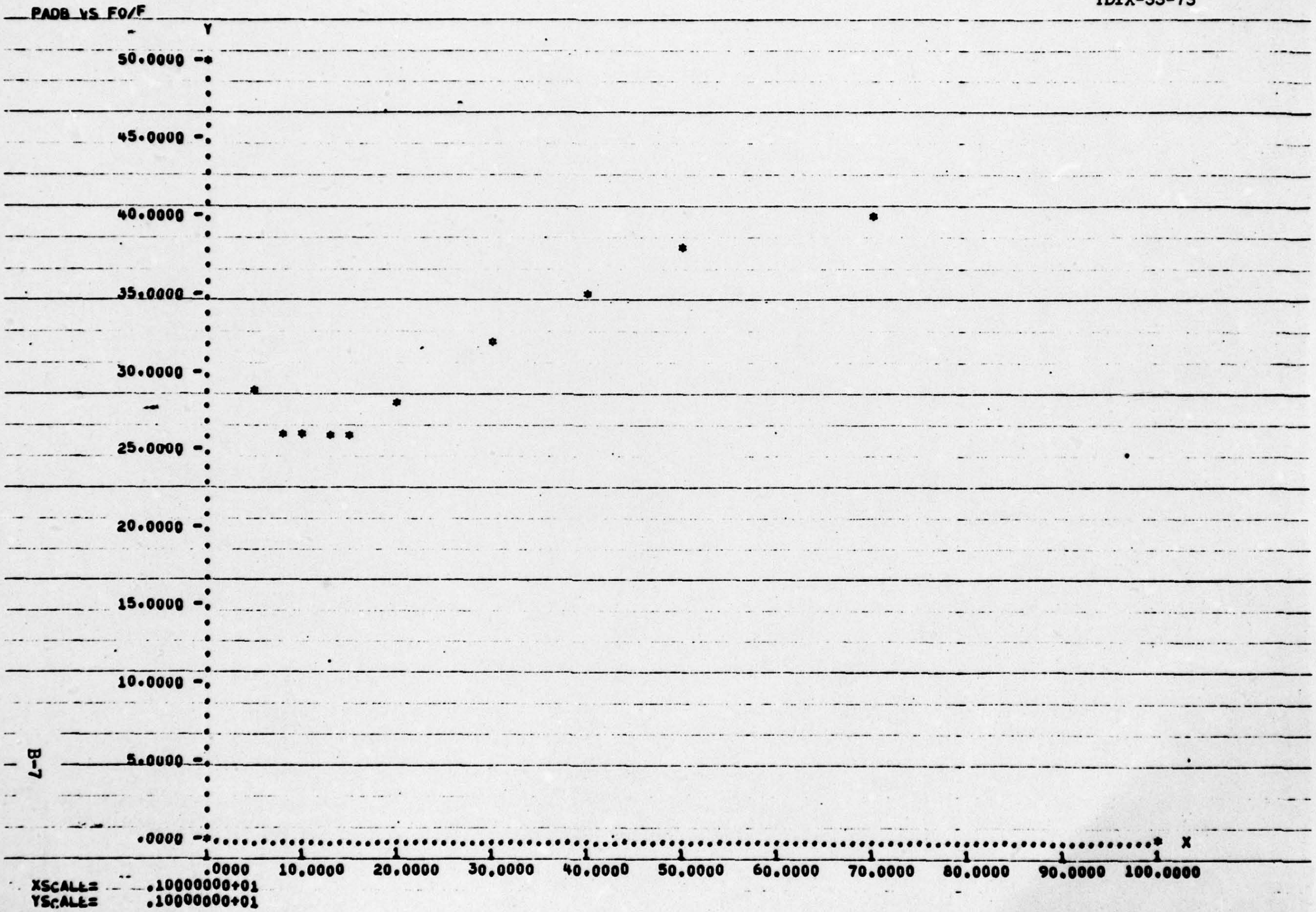
D= .0

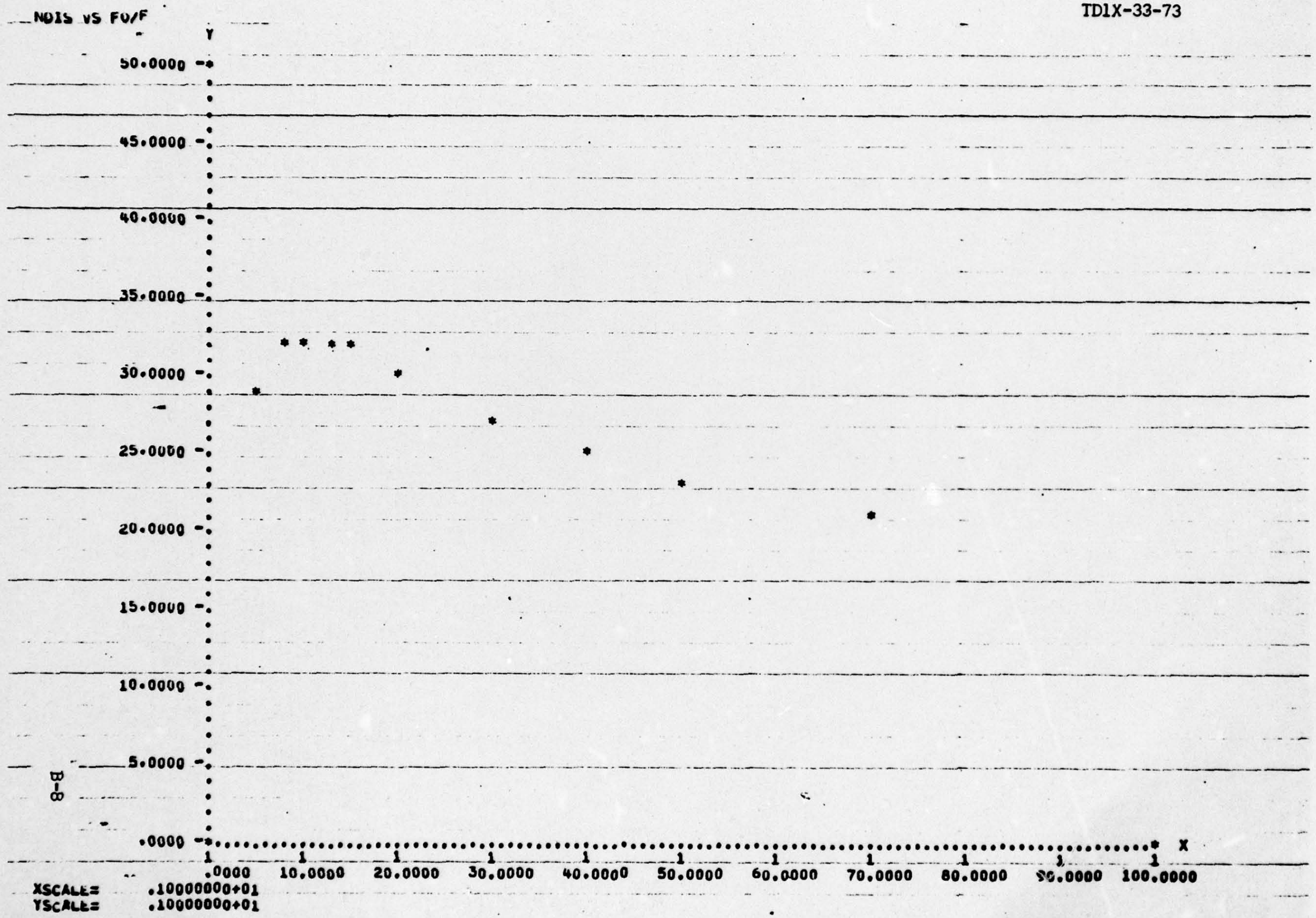
S= 35.

C= 1479.

A= .3947

F	PAWO	FU/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	20.6	5.00	15.000	.000241	2079.	4.	521.9	27.1	89.9	126.4	149.9	-36.5	717.2	29.3	2.3
3.000	20.5	7.50	22.500	.000506	988.	6.	165.3	30.6	89.4	127.9	154.9	-38.5	444.6	31.6	1.1
3.000	20.4	10.00	30.000	.000846	591.	8.	74.1	33.1	90.9	130.3	159.9	-39.4	441.5	32.3	-.8
3.000	25.9	12.50	37.500	.001257	404.	10.	40.6	35.0	90.2	131.7	163.2	-41.5	387.7	32.3	-2.8
3.000	26.0	15.00	45.000	.001657	302.	12.	25.3	36.6	90.1	133.4	166.5	-43.3	400.8	31.8	-4.8
3.000	27.7	20.00	60.000	.002510	199.	16.	12.5	39.1	90.6	137.6	173.1	-47.0	582.7	30.3	-8.8
3.000	32.2	30.00	90.000	.004021	124.	24.	5.2	42.6	90.6	145.6	184.7	-55.1	1659.7	27.1	-15.5
3.000	35.5	40.00	120.000	.005106	98.	32.	3.0	45.1	90.3	151.4	193.0	-61.1	3532.9	24.7	-20.4
3.000	36.2	50.00	150.000	.006109	82.	40.	2.1	47.1	90.8	156.1	199.6	-65.2	6649.4	22.6	-24.4
3.000	39.8	70.00	210.000	.007653	65.	56.	1.2	50.0	89.5	160.6	207.1	-71.1	9623.6	20.5	-29.5
3.000	.0	100.00	300.000	.009969	50.	80.	.6	53.1	82.2	.0	210.4	-77.7	L* > 210.		


PADB VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01


NOIS VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

U= .0

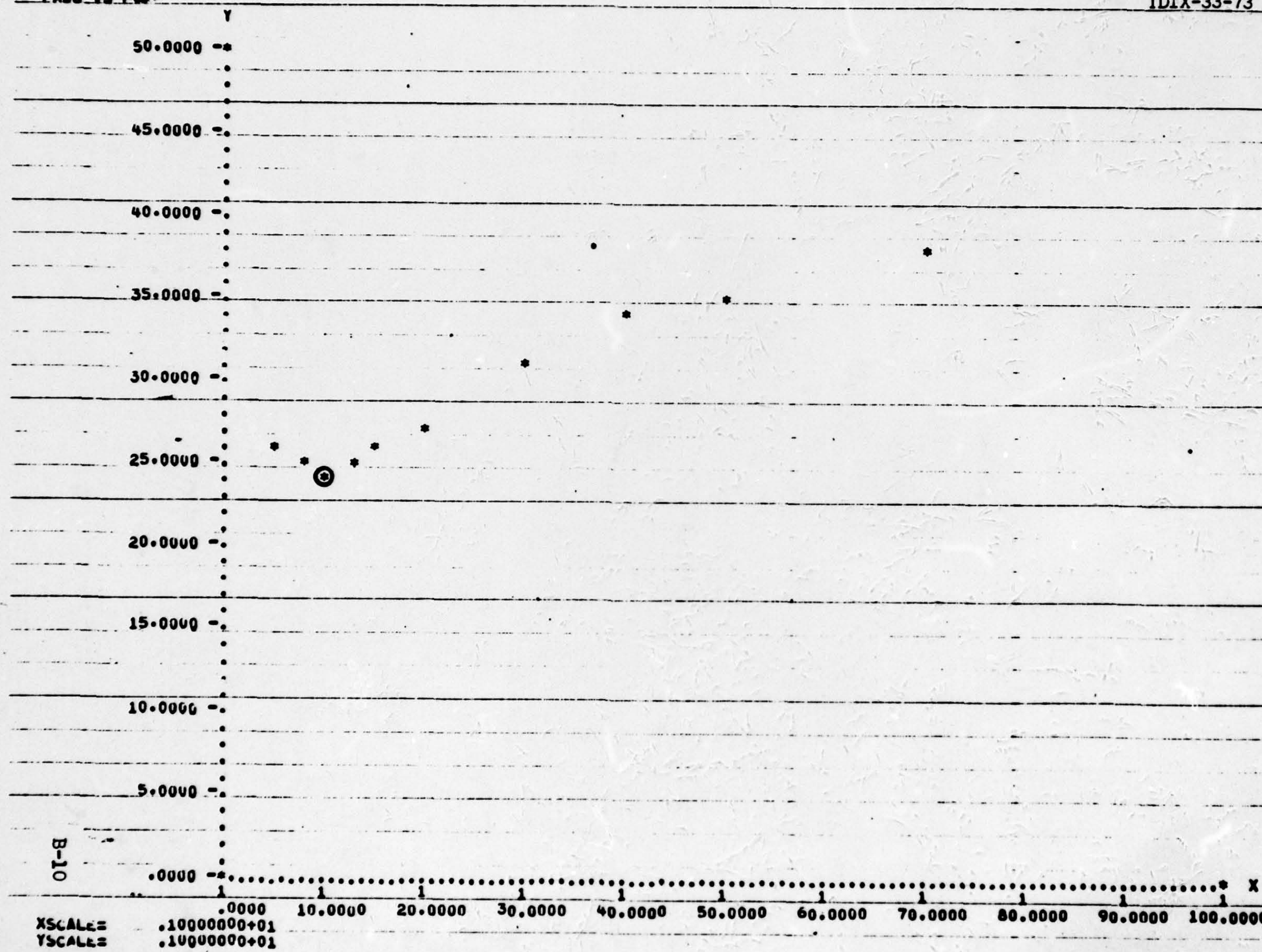
S= 35.

C= 1479.

A= .7854

F	PADB	FO/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	26.6	5.00	15.000	.000241	2079.	8.	260.9	30.1	90.2	127.2	150.8	-37.0	433.9	32.2	2.1
3.000	25.1	7.50	22.500	.000506	988.	12.	82.7	33.6	90.7	129.5	156.6	-38.8	325.5	34.1	.5
3.000	24.3	10.00	30.000	.000846	591.	16.	37.1	36.1	89.9	131.2	160.7	-41.2	267.1	34.4	-1.7
3.000	24.6	12.50	37.500	.001237	404.	20.	20.3	38.0	90.1	133.4	164.8	-43.3	283.8	33.9	-4.1
3.000	25.5	15.00	45.000	.001657	302.	24.	12.6	39.6	90.7	135.9	169.0	-45.2	355.0	33.1	-6.5
3.000	27.1	20.00	60.000	.002510	199.	32.	6.3	42.1	90.2	140.0	175.6	-49.9	516.1	31.5	-10.6
3.000	30.6	30.00	90.000	.004021	124.	48.	2.6	45.6	89.6	147.3	186.4	-57.7	1215.0	28.6	-17.0
3.000	34.1	40.00	120.000	.005186	96.	64.	1.5	48.1	90.3	153.1	194.6	-62.8	2586.3	26.4	-21.8
3.000	35.2	50.00	150.000	.006109	82.	80.	1.0	50.1	89.5	156.1	199.6	-66.6	3324.7	25.1	-25.0
3.000	38.5	70.00	210.000	.007653	65.	112.	.6	53.0	90.4	162.3	208.7	-71.8	7044.9	22.4	-30.6
3.000	.0	100.00	300.000	.009969	50.	159.	.3	56.1	81.0	.0	210.4	-78.8	L* > 210.		

PADB VS FO/F


Y
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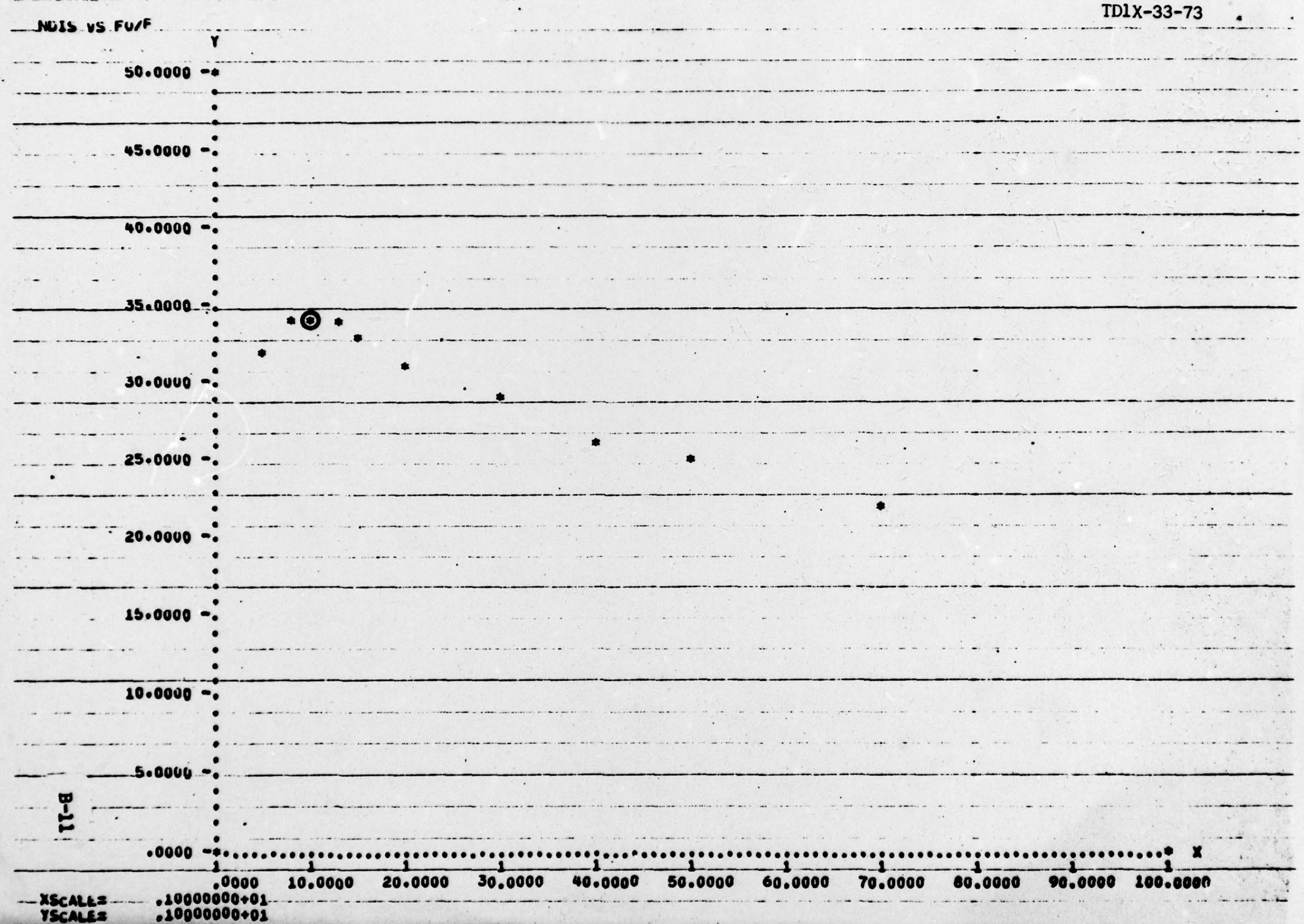
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
X
XSCALE= .10000000+01
YSCALE= .10000000+01


NDIS VS FU/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

AD-A080 036 NAVAL UNDERWATER SYSTEMS CENTER NEWPORT RI F/G 17/1
COMPUTER AIDED PARAMETRIC SONAR DESIGN.(U)
MAY 73 E C GANNON, R P PINGREE
UNCLASSIFIED NUSC-TM-TDIX-33-73 NL

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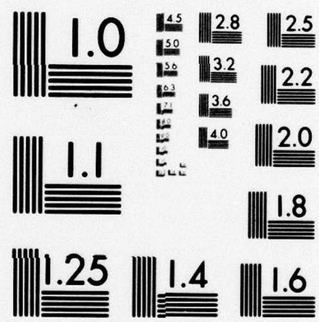

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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TM No.
14 NUSC-TM-TD1X-33-73

NAVAL UNDERWATER SYSTEMS CENTER
Newport, Rhode Island 02840

9 Technical ~~Memorandum~~

6 COMPUTER AIDED PARAMETRIC SONAR DESIGN,

11 23 May 1973

Prepared by: Edmund C. Gannon

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12 42

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ABSTRACT

A computer program was written that enables the design of parametric sonars. This program accepts as inputs temperature, salinity, depth, estimates of projector area, desired secondary source level and secondary frequency. The program computes various parametric sonar quantities among them primary source level, directivity index and primary operating frequency. The program actually generates a matrix of possible design values that permit the designer to choose those which best suit his needs based on other system considerations.

The design program is written in Fortran V for use on the Univac 1108. The program is completely general and any of the input parameters can be varied while holding the others constant. A discussion on how to use the program as well as a sample example is included.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under Project No. A-614-19, Principal Investigator, Dr. A. J. Van Woerkum, Code TC.

The authors of this memorandum are located at the New London Laboratory, Naval Underwater Systems Center, New London, Connecticut 06320.

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INTRODUCTION

From the viewpoint of the individual who is faced with the design of a parametric sonar, the calculations involved seem repetitive and in some cases endless. The Mellen and Moffett[1] curves together with the appropriate equations given in the reference contain all of the necessary information. However, the information is presented in such a way as to make it easy to work through the curves and calculations to analyze the parametric operation of existing projectors and systems but it is difficult and not straightforward to work backward through the curves and equations to design a projector system.

There is a solution which is offered by Moffett[2] that uses a "load line" type of technique similar to that used in vacuum tube circuit design. This is good for a small number of possible designs of a given parametric sonar. The method requires, however, repetitive computations to arrive at the dimensionless parameters 1/(2)(AL)(RO) for each possible parametric stepdown ratio (the ratio of the parametric difference frequency to the mean projector driving frequency FO/F). The term (AL) is absorption in nepers per meter while RO is the Rayleigh distance. Appendix B contains a complete glossary of terms. The "load line" method is presently limited by the number of families of curves available for the different stepdown ratios and the accuracy of interpolating between the given curves of a given family.

A means, therefore, was devised where the whole design process was automated using the Univac 1108 computer. In essence, computer aided design. The solution allows the designer to work from a known secondary source level (LSS) and a known secondary frequency (F) for a range of values of projector size (A), primary source level per tone (LSP) and a given stepdown ratio (FO/F). The computer program will build a matrix of possible designs that can then be compared with other factors to achieve a workable and realistic design.

BACKGROUND

In parametric sonar calculations, two distinct and different problems arise. One is that of the analysis of existing sonar to predict their parametric operating characteristics. The other is the design of parametric sonars having a given set or range of output source levels and frequencies.

In the first problem, one usually knows the primary operating frequency (FO), the primary source level (LSP), and the projector area (A). From these one obtains the secondary source level (LSS) and secondary directivity index (NDIS) for a given downshift ratio (FO/F) by using the Mellen and Moffett

curves and the appropriate formulae. In summary, we know

FO, LSP and A.

We find

LSS, FO/F, NDIS.

The Mellen and Moffett curves and the associate equations readily lend themselves to solving this problem because of the way the equations and the curves are set up.

The second problem is one of designing a parametric sonar starting from "scratch" where one only knows the desired, or the range of desired, LSS, F, and NDIS and wants to find FO, LSP and A. At first glance one would say, "Why not just work backwards through the equations with the aid of the Mellen and Moffett curves?" Alas, life is not so simple. The equations depend on a knowledge of FO, and A. In other words, something must be known about the projector before starting. Unfortunately, determining FO, A, and LSP is the goal of the design process. This is just the opposite of the analysis previously discussed. There is a method that has been proposed by Moffett that utilizes the "load line" technique previously mentioned. This method is excellent when an exact FO and A are sought for a given LSS, F, and NDIS. The method becomes time consuming and requires tedious repetitive calculations when a range of values is sought and when one needs numerous possibilities in order to examine and choose an optimum solution based on factors other than just parametric sonar considerations. What is needed is a method of constructing a matrix of possible parametric sonar designs for the designer to weigh in consort with associated system parameters. In summary for this situation we know

LSS, FO/F, NDIS

and we want to find

FO, LSP and A.

SOLUTION

The solution to the problem is computer aided design. A program was written that allows the designer to vary F, A, LSS, and FO/F in order to construct the desired design matrix. The program compilation is given in Appendix A. This program is versatile enough so that three other parameters temperature (T), salinity (S) and depth (D) can be varied in coarse steps and their effects on the design studied. The results are tabulated and two on-line plots are possible. The results of a sample example are shown in Appendix B. The on-line plots can be of any two variables and each plot can be altered by changing a computer card.

At present, one plot is acoustic power in dB (PADB) vs. FO/F for a given LSS with the parameters T, S, D, F and A held constant. Then either LSS, F, or A can be changed and another plot made. Thus, one can examine the range of possible designs that are within the desired power budget and select a reasonable one. The second plot is secondary directivity index (NDIS) vs FO/F for the same given conditions as in the previous plot. From this the designer can select the necessary quantities for a desired range of NDIS. Normally, many plots will be produced resulting in families of LSS curves with NDIS and PADB plotted against FO/F with T, S, D, constant for many combinations of F and A. Once a set of parameters is decided upon, the appropriate exact constants can be obtained from the tabulation.

One thing that has been done to aid in plot comparisons is to force the plots to a convenient common scale. This was done by the use of two dummy points on each plot. This was necessary because the routine as originally compiled by Gordon[3] automatically scaled the axis for the plotting range. For the desired comparisons of plots, such scaling is undesirable.

The program is outlined in a simplified flow chart shown in Figure 1. It operates as follows: The inner loop computes parametric sonar design constants for each of a sequence of FO/F values. This is done for each of a sequence of LSS values in the input data (LSS1). Next, the two inner loops are repeated for a sequence of values for A and finally these three innermost loops are repeated for each value of F in the input data. These four loops generate a matrix of possible designs for the ranges of FO/F, LSS, A, and F chosen. Each matrix is built up for constant values of T, S, and D. The values for T, S, and D can be altered by changing them when the data is programmed into the computer.

The plots as presently compiled plot after each sequence of FO/F for a given LSS. Thus, a family of curves of different LSS values is generated. These are for each combination of T, S, D, F, and A and are plotted with FO/F as the horizontal axis on each plot. The vertical axis on plot number 1 is PADB while the vertical axis on plot number 2 is NDIS.

A more detailed flow chart is shown in Figure 2. It shows an expansion of the computational block diagram of Figure 1. Thus, the location of the various calculations are shown along with the appropriate tests required to keep the program bounded. Once the data is entered, the calculations leading to the quantity 1/(2)(AL)(RO) are made where the attenuation loss is (AL) and the Rayleigh distance is (RO). This quantity 1/(2)(AL)(RO) together with the FO/F and a quantity X is entered into a numerical integration subroutine devised by Goldstein[4]. The X is a parameter that ties the integration to a scaled source level (L^*) which is a normalized parametric quantity in the Mellen and Moffett theory. The output of the numerical integration enters into several simple computations, the results of which are tested to see if they fall within the

proper programmed bounds. If the tests are failed, a new value of X is chosen and the integration routine is redone and retested. Depending on how the tests are passed, the program either proceeds to calculate further parametric sonar quantities for the given solution of the numerical integration or the program recognizes that the numerical integration has searched as far as it can. In any event, the program will proceed to readout the results in a table then recycle to the next FO/F in the innermost loop. Once the desired LSS values has been completely investigated, the computer constructs the two on-line plots previously mentioned. The program then recycles until all possible values of F, A, LSS and FO/F have been investigated and all plots completed. The program then terminates. The detailed flow chart (Figure 2) references equations which are tabulated in Table I.

In essence, the program takes some known values for a given condition and hunts, by means of a numerical integration routine and specific tests, for other needed values to completely describe a parametric sonar. Since usually there is a range of desired values, the program builds a matrix of possible solutions. The accuracy of these solutions depends on the accuracy of the parameter X used in the numerical integration. Presently, the solution calculates an LSS which is compared with the input LSS (LSS1). The calculated value has a tolerance of ± 0.82 dB. The resultant LSP, parametric gain (G), acoustic power (PA and PADB), and primary frequency directivity index (NDIP) all have a tolerance of ± 0.41 dB. The NDIS has a ± 0.82 dB tolerance.

PROGRAM OPTIONS

The design program has certain options as a result of the general form in which it is written. The program contains four nested loops any of which can be varied or held constant by appropriate input data on the input data cards. The plots can be varied, however, this may involve repositioning the plot in the program as well as changing two program cards. The user may have to redimension the storage associated with the loops preceding the plot in order to be sure the data computed is retained until the plot is called.

Equation No.	Equation
1.	$X_{(I+1)} = 1.1X_I$ FOR 86 VALUES FROM $X = 0.090909$
2[5].	$FT = 21.9 \times 10^{6-(1520/(T+273))}$ kHz
3[5].	$AL = (1/8.68)(1/914.4)\left\{\left[(1.86\times10^{-2})(S)(FT)(FO)^2/\left[(FT)^2+(FO)^2\right]\right] + \left[2.68\times10^{-2}(FO)^2/FT\right] + \left[0.1(FO)^2/(1+(FO)^2)\right]\right\}(1-6.33233\times10^{5}D)$ NEPERS/METER
4[5].	$C = 1449.2 + 4.623T - 0.0546(T^2) + 1.391\ (S-35) + 0.017D$ METERS/SECOND
5[6].	$NDIP = 10\ LOG_{10}(4\pi A\ (FO)^2(10^3)^2/C^2)$ DB
6.	$PADB = LSP - 70.8 - NDIP$ DB
7.	$PA = ANTILOG\left[(1/10)(LSP-70.8-NDIP)\right]$ WATTS
8[1].	$NDIS = (NDIP) + 3 - 10\ LOG_{10}\left[1 + ((FO)/F)(2\pi(AL)(RO) + X)\right]$ DB

TABLE I

PROGRAM USAGE AND SAMPLE EXAMPLE

In order to use the program, the user must stack appropriately formatted data cards in a fixed order at the end of the program. There are six different types of cards. These cards will now be discussed in order from front to back of the stack.

The first type of card contains only one card and comes first in the data. It is formatted into 4 fields of one integer number per field. Each number must be right justified in a field width of five (Fortran V statement (I5)). The first field uses columns 1 through 5 and contains the number of F values. The second field uses columns 6 through 10 and contains the number of A values. The third field uses columns 11 through 15 and contains the number of LSS values. The fourth field uses columns 16 through 20 and contains the number of FO/F values plus 1. This arrangement of fields is summarized in Table 2.

The second type of card contains only one card and it is the 2nd card in the data. It is formatted into 3 fields. Each field contains a number that is written in a floating point format which is right justified in a field width of 10 with a 4 decimal place accuracy (Fortran V statement (F10.4)). The first field uses columns 1 through 10 and contains the value for T. The second field uses columns 11 through 20 and contains the value for 5. The third field uses columns 21 through 30 and contains the value for D. These fields are also summarized in Table 2.

The third through sixth type of cards may contain more than 1 card for each type but only one value for each card. Thus, one must use as many cards for each type as there are values associated with that type and the cards for each type must be grouped together. Each number is written in a floating point format which is right justified in a field width of 10 with a 5 decimal place accuracy (Fortran V statement (F10.5)). Each third type of card gives a value for F. Each fourth type of card gives a value for A. Each fifth type of card gives an input value for LSS (LSS1). Lastly, each sixth type of card gives a value for FO/F. Each of these field layouts are summarized in Table 2.

Card Type	Card Columns	Fortran IV Format	Agreement
1	1-5	I5	No. of F values
	6-10	I5	No. of A values
	11-15	I5	No. of LSS values
	16-20	I5	No. of FO/F values
2	1-10	F10.4	T in deg C
	11-20	F10.4	S in PPT
	21-30	F10.4	D in meters
3	1-10	F10.5	F in kHz
4	1-10	F10.5	A in sq. meters
5	1-10	F10.5	LSS in dB
6	1-10	F10.5	FO/F

TABLE 2

DATA CARD FORMATS

The use of this program requires the input of data from a program stored on tape in the NUSC New London Laboratory Univac 1108 files. This is tape U183. Different parameter plots may be made by simply changing the call to plot (Call Plot A) statements. There are two such plots in the program. The plot routine can be eliminated by removing the two call to plot cards which are located adjacent to each other in the program. The rest of the program should run and the table of results printed.

A sample example will now be discussed. Suppose we want to design a parametric sonar that has the following specifications:

LSS = 90 dB//1μbar-meter

F = 3 kHz

N_{DI} = 30 dB to 35 dB

and the power budget is such that we wish to minimize its consumption. Assume that the system will work in the ocean (S = 35 ppt) and that the system must be capable of operating in the winter (T = 7°C) on the surface (D = 0). The data is programmed as shown in Figure 3. The tables of results are shown in Appendix B along with 3 sets of plots. Examination of the results shows several design possibilities all within the region of a dip in the PADB plots. If it were not possible to examine so large a quantity of points, the dip quite possibly would go unnoticed because there is a tendency for the unwitting designer to assumethat increased stepdown ratio means increased power consumption. Apparently, this is not always true. When the desired points are isolated on the plots, the designer then can go to the tables and from them he can determine the design that gives the desired source level within the NDIS restrictions. The desired design for the sample example is the one underlined in the appropriate table of Appendix B and encircled on each of the associated PADB and NDIS vs FO/F plots. The selected design has the following parameters:

FO/F = 10

FO = 30 kHz

LSP = 131.2 dB//1μbar-meter

NDIP = 36.1 dB

NDIS = 34.4 dB

and PA = 267.1 watts/each primary frequency.

Other related quantities can be obtained from the data tables. For different applications these quantities may assume importance and thus are readily available if design tradeoffs become necessary.

CONCLUSION

A computer aided parametric sonar design program has been written for the UNIVAC 1108. This program allows the designer to take a given secondary source level (LSS), secondary frequency (F) and secondary directivity index (NDIS) and compute a range of possible parametric sonar designs that will satisfy his needs. Thus, the selection of sonar parameters is no longer limited by the difficulty of examining a range of possible parametric designs. The sonar designer can now construct a matrix of possible designs then base the final selection on which of these designs best fits the other systems parameters being considered. By means of computer aided design, literally hundreds of possible designs for a given situation can be investigated in a short time.

REFERENCES

1. Mellen, R. H. and M. B. Moffett, "A Model for Parametric Radiator Design," USN Journal of Underwater Acoustics, Vol. 22, No. 2, April 1972 (Unclassified).

2. Moffett, M. B., "Load Line Technique for Parametric Design," unpublished communication in 1972.

3. Gordon, R. L., "A Fortran V Plotting Routine for the Univac 1108 High Speed Printers," USL Tech Memo No. 2242-291-68, 25 July 1968 (Unclassified).

4. Goldstein, M., "On A numerical Integration in Parametric Sonar Research," NUSC Tech Memo No. PA4-268-71, 21 Oct 1971, (Unclassified).

5. Urick, R. J., "Principles of Underwater Sound for Engineers," McGraw Hill, Copyright 167, pages 88-96.

6. "The Design and Construction of Magnetostriction Transducers," NDRC Div 6 Report Vol. 13, dated 1946, p. 128.

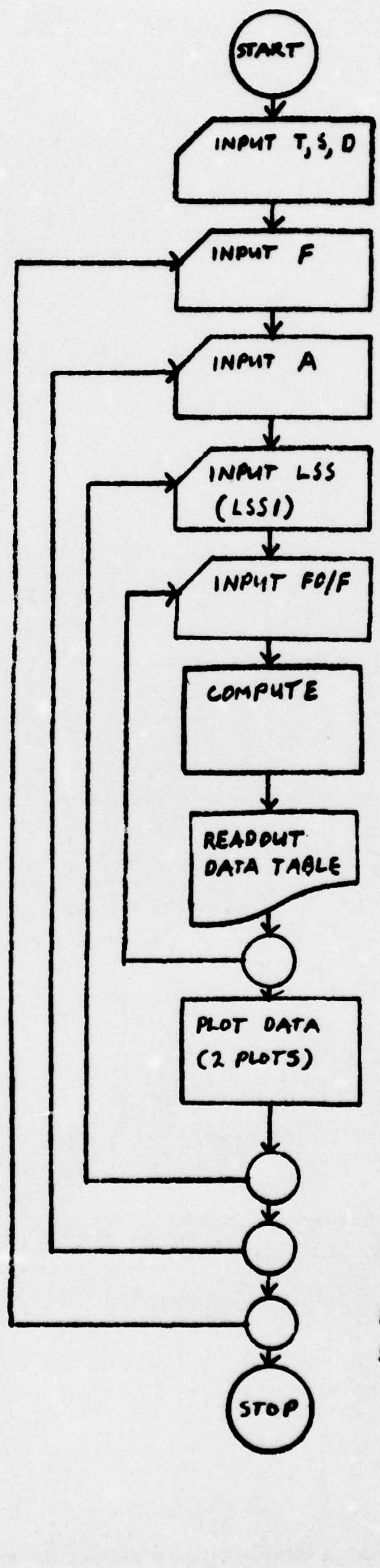
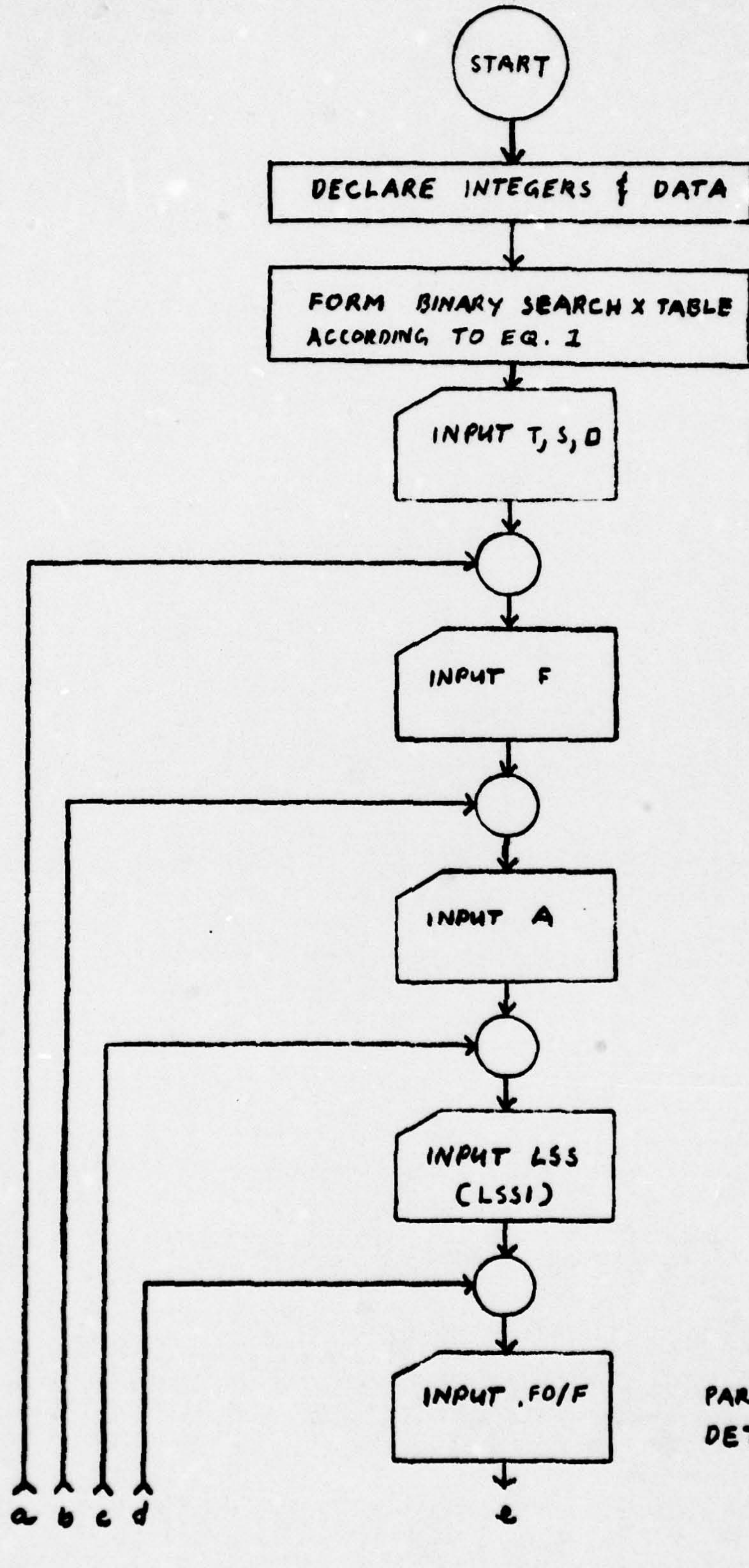


FIGURE 1

PARAMETRIC SONAR DESIGN,
SIMPLIFIED FLOW CHART



NOTE:
FOR EQUATIONS SEE TABLE 1

FIGURE 2

PARAMETRIC SONAR DESIGN, DETAILED FLOW CHART

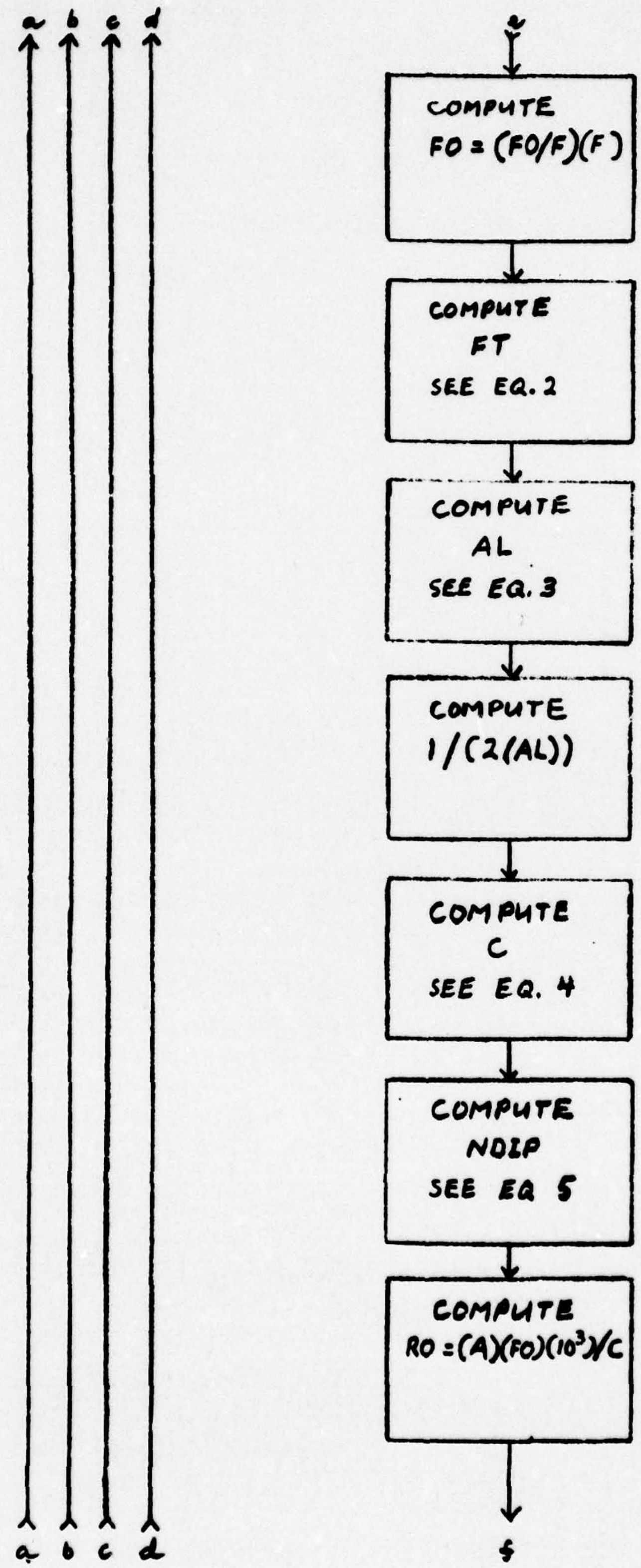


FIGURE 2 (CONT. 1)

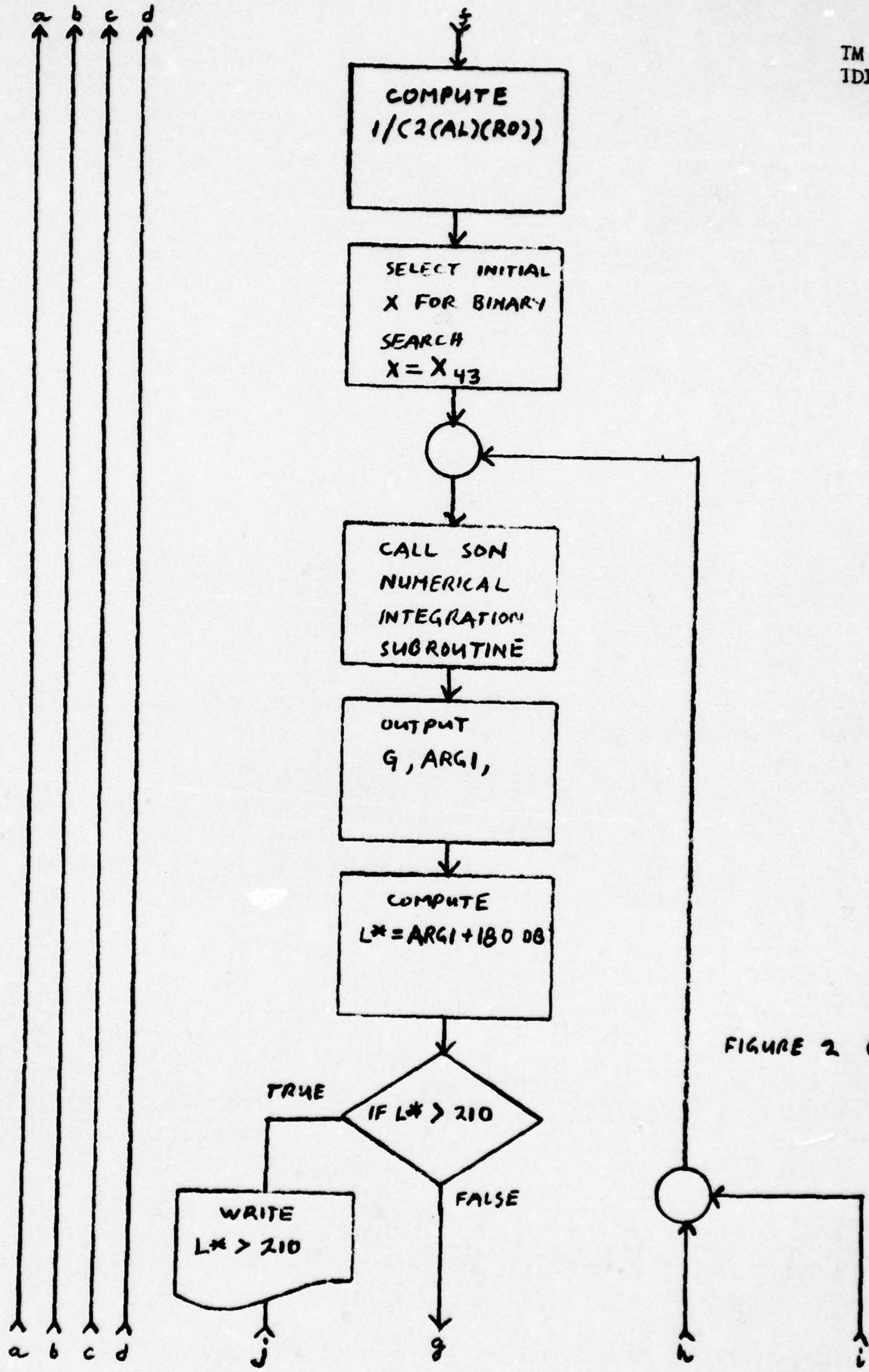


FIGURE 2 (CON'T 2)

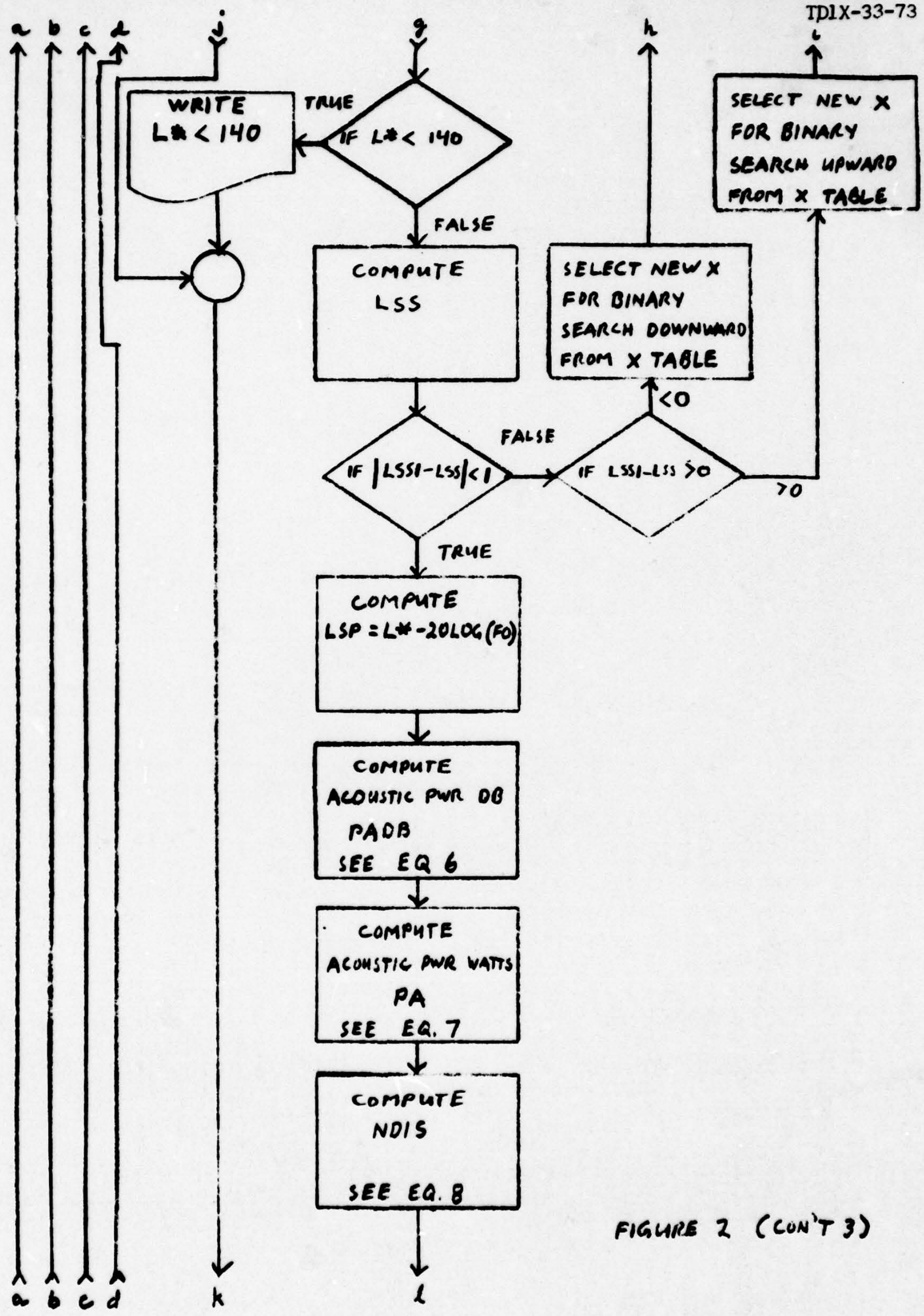


FIGURE 2 (CON'T 3)

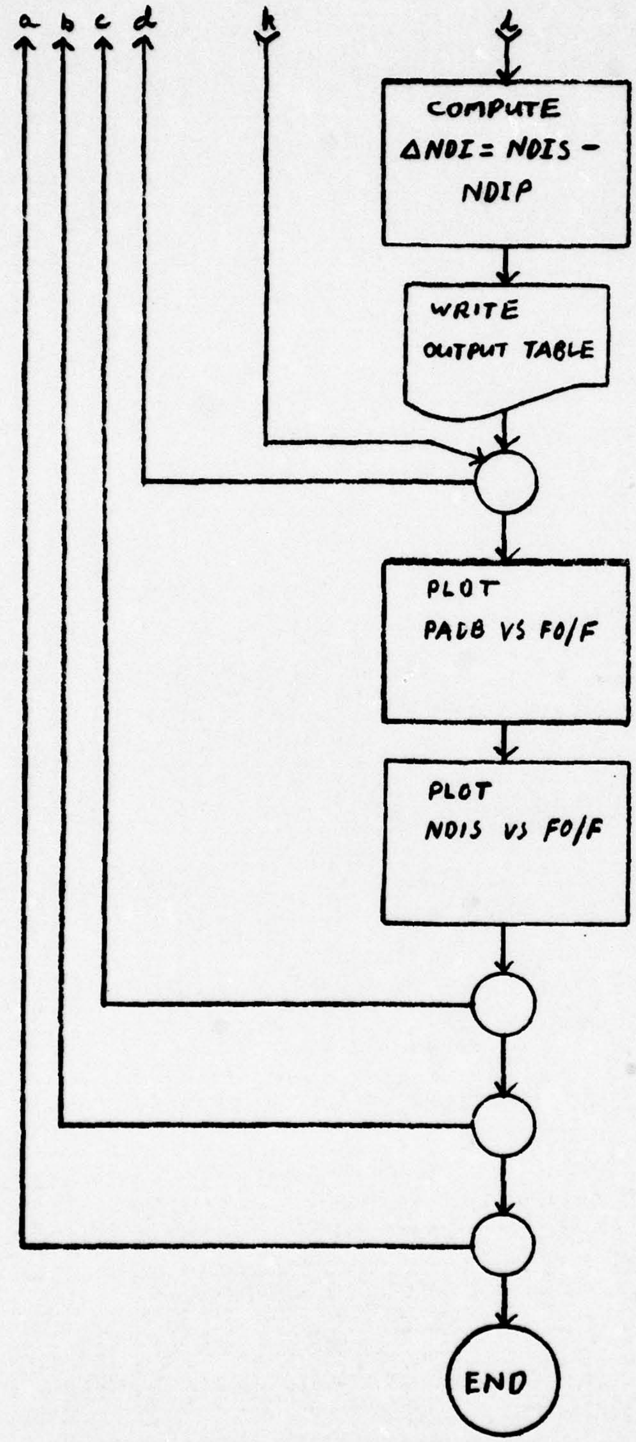


FIGURE 2 (CON'T. 4)

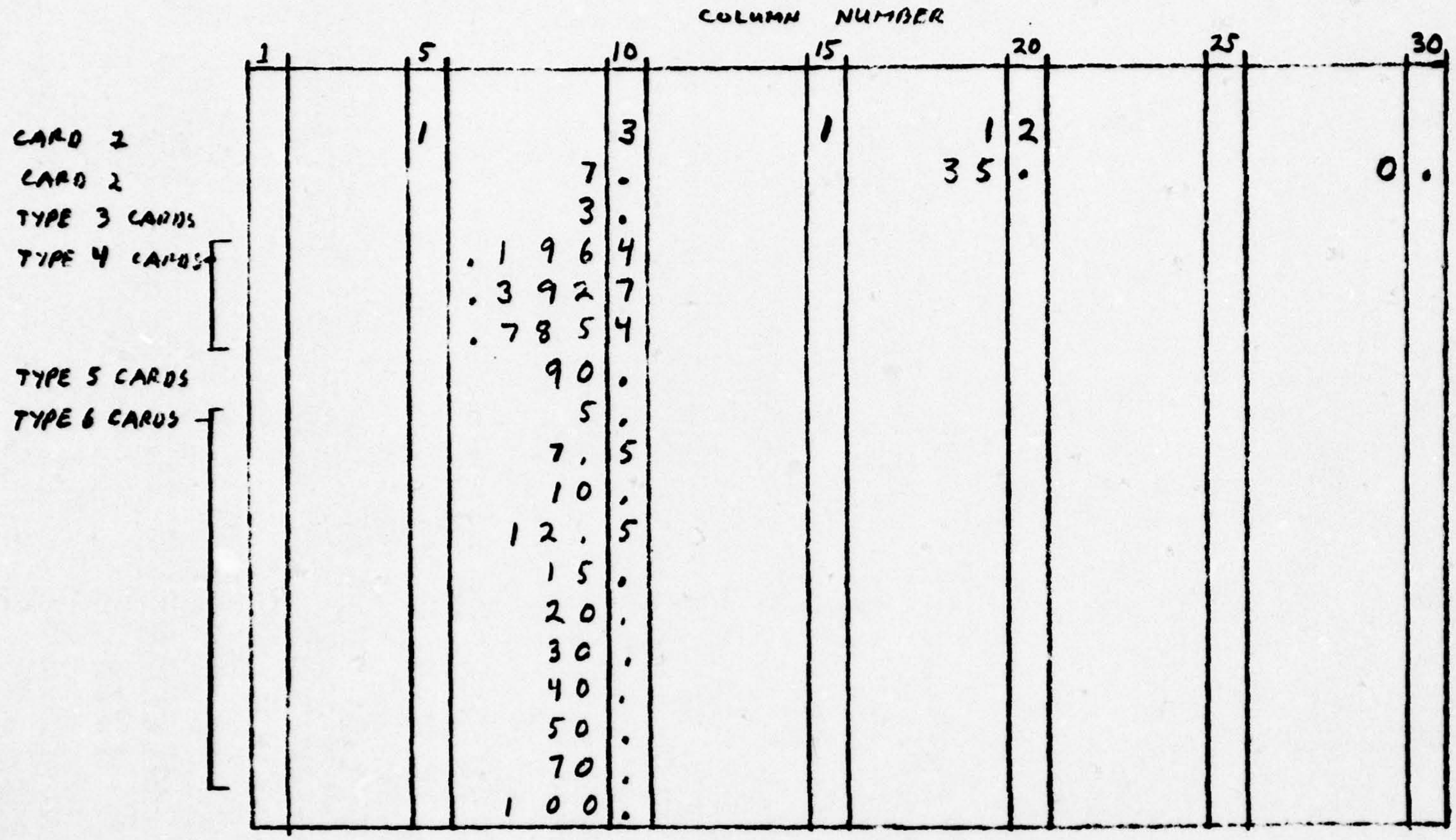


FIGURE 3

SAMPLE EXAMPLE DATA FORMAT

APPENDIX A

PROGRAM COMPILATION

The program compilation shown here is complete with subroutines except for the plot subroutine. That particular one was on tape and was not compiled as was the material that was put in by means of a deck of cards.

```
    FOR SUB,SUB                                                                                21:34:46. 50
UNIVAC 1108 FORTRAN V LEVEL 2206 0026     (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:46

   SUBROUTINE SUB        ENTRY POINT 000067

   STORAGE USED: CODE(1) 000103; DATA(0) 000020; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   BLK    000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   DSINH
    0005   DEXP
    0006   DSQRT
    0007   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0003 D 000000 ARO      0003 D 000006 E       0003 D 000002 GKDKO     0000    000012 INJP$     0000 D 000000 T
    0003 D 000004 X


00101      1*          SUBROUTINE SUB(A,J,H,F)
00103      2*          IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00104      3*          COMMON/BLK/ARO,GKDKO,X,E
00105      4*          T=A+J*H
00106      5*          F=DSINH(T)
00107      6*          T=1.0D0+((X*T)**2)/4.0D0
00110      7*          IF(ARO.GT.0.0D0) E=DEXP(-F*ARO)
00112      8*          F=F**2
00113      9*          F=(1.0D0+F)/(1.0D0+F*GKDKO**2)
00114     10*          F=E*(DSQRT(F)/T)
00115     11*          RETURN
00116     12*          END

     END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
   FOR ROM,ROM                                                                                          21:34:47. 40
UNIVAC 1108 FORTRAN V LEVEL 2206 0026     (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:47

   SUBROUTINE ROM        ENTRY POINT 000246

   STORAGE USED: CODE(1) 000275; DATA(0) 000060; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   SUB
    0004   NEXP1$
    0005   NEXP6$
    0006   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001    000071 120G      0001    000120 130G      0001    000033 4L        0000 D 000003 F       0000 D 000005 FN
    0000 D 000000 H          0000    000031 INJP$     0000 I 000015 IU         0000 I 000012 J       0000 I 000013 J1
    0000 I 000002 K          0000 I 000014 L          0000 I 000011 M          0000 D 000007 SIG


00101      1*          SUBROUTINE ROM(A,B,W,EPS,IV,NMX)
00103      2*          DIMENSION W(NMX,NMX)
00104      3*          IMPLICIT DOUBLE PRECISION (A-H,O-Z)
00105      4*          H=B-A
00106      5*          K=0
00107      6*          CALL SUB(A,0,H,F)
00110      7*          FN=F
00111      8*          CALL SUB(A,1,H,F)
00112      9*          W(1,1)=((F+FN)*H)/2.0D0
00113     10*        4 K=K+1
00114     11*          H=H/2.0D0
00115     12*          SIG=0.0D0
00116     13*          M=2**(K-1)
00117     14*          DO 1 J=1,M
00122     15*          J1=2*J-1
00123     16*          CALL SUB(A,J1,H,F)
00124     17*        1 SIG=SIG+F
00126     18*          W(K+1,1)=W(K,1)/2.0D0+H*SIG
00127     19*          DO 2 L=1,K
00132     20*          IU=K+1-L
00133     21*          IV=L+1
00134     22*        2 W(IU,IV)=(4.0D0**(IV-1)*W(IU+1,IV-1)-W(IU,IV-1))/(4.0D0**(IV-1)-1.
00134     23*         1D0)
00136     24*          IF(ABS(W(IU,IV)-W(IU,IV-1)).LT.ABS(W(IU,IV))*EPS) RETURN
00140     25*          GO TO 4
00141     26*          END

     END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
   FOR SON,SON                                                                                 21:34:48.364
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:48

   SUBROUTINE SON        ENTRY POINT 000134

   STORAGE USED: CODE(1) 000160; DATA(0) 011664; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   BLK    000010

   EXTERNAL REFERENCES (BLOCK, NAME)

    0004   ROM
    0005   DLOG
    0006   DATAN
    0007   DLOG10
    0010   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000045 1L        0000 D 011612 A       0000 D 011620 ALN1     0003 D 000000 ARO      0000 D 011614 B
    0003 D 000006 E         0000 D 011610 EPS     0000 D 011622 FAC      0003 D 000002 GKDKO    0000 D 011616 GKDKOS
    0000   011650 INJP$     0000 I 011624 IV      0000 D 000000 W        0003 D 000004 X


 00101      1*           SUBROUTINE SON (RARO,RKDKO,ARG,ANS,AIN,NMX)
 00103      2*           IMPLICIT DOUBLE PRECISION (A-H,O-Z)
 00104      3*           COMMON/BLK/ARO,GKDKO,X,E
 00105      4*           DIMENSION W(50,50)
 00106      5*           EPS=.5D-05
 00107      6*           A=0.0
 00110      7*           B=20.0
 00111      8*           E=1.0D0
 00112      9*           ARO=0.0D0
 00113     10*           IF(RARO.GT.ARO) ARO=1.0D0/RARO
 00115     11*           GKDKO=1.0D0/RKDKO
 00116     12*           GKDKOS=GKDKO**2
 00117  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00117     13*           IF(RARO.EQ.0.0D0) GO TO 1
 00121     14*           ALN1=DLOG(RKDKO)
 00122     15*           B=DLOG((84.0D0+ALN1)*RARO)
 00123     16*         1 FAC=GKDKOS*(X/2.0D0)
 00124     17*           CALL ROM(A,B,W,EPS,IV,50)
 00125     18*           AIN=W(1,IV)
 00126  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
 00126     19*           IF(RARO.EQ.0.0D0) AIN=AIN+2.0D0*RKDKO*(1.5707963267948900-DATAN(10
 00126     20*          1.0D0*X))/X
 00130     21*           AIN=FAC*AIN
 00131     22*           ARG=20.0D0*DLOG10(X)
 00132     23*           ANS=20.0D0*DLOG10(AIN)
```

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00133     24*          RETURN
00134     25*          END

     END OF COMPILATION:          2 DIAGNOSTICS.
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@     FOR SONAR,SONAR                                                                    21:34:49.464
UNIVAC 1108 FORTRAN V LEVEL 2206 0026      (EXEC8 LEVEL E1201-0011)
THIS COMPILATION WAS DONE ON 14 JUN 73 AT 21:34:49

    MAIN PROGRAM

    STORAGE USED: CODE(1) 001012; DATA(0) 004536; BLANK COMMON(2) 000000

     COMMON BLOCKS:

     0003     BLK      000010

    EXTERNAL REFERENCES (BLOCK, NAME)

     0004     SON
     0005     PLOTA
     0006     NRDU$
     0007     NIO2$
     0010     NEXP6$
     0011     NIO1$
     0012     NWDU$
     0013     ALOG10
     0014     DLOG10
     0015     NSTOP$

    STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0000     004023 100F     0000     004002 101F     0000     004003 102F     0000     004025 103F     0000     004242 104F
     0000     004262 105F     0000     004321 106F     0000     004346 107F     0000     004356 112F     0000     004402 113F
     0000     004426 114F     0001     000016 117G     0001     000523 13L      0001     000531 14L      0001     000541 15L
     0001     000146 156G     0001     000160 164G     0001     000557 17L      0001     000172 172G     0001     000204 200G
     0001     000573 200L     0001     000234 206G     0001     000671 210L     0001     000237 211G     0001     000247 214G
     0001     000717 220L     0001     000312 236G     0001     000430 257G     0001     000744 4L       0001     000571 5L
     0000 R   001130 A        0000 R   002424 ADUM     0000 D   003410 AIN      0000 R   001750 ALPHA    0000 D   003416 ANS
     0000 R   003244 ANS1     0000 D   003414 ARG      0000 R   003100 ARG1     0003 D   000000 ARO      0000 R   003760 C
     0000 R   003753 D        0000 R   001274 DELNDI   0000 R   004000 DUM      0003 D   000006 E        0000 R   000764 F
     0000 R   001440 FO       0000 R   003764 FT       0003 D   000002 GKDKO    0000 I   003737 I        0000 I   003754 IA
     0000 I   003755 IB       0000 I   003756 IC       0000 I   003734 ICARD    0000 I   003774 ICONST   0000 I   003757 ID
     0000 I   003776 IDUM1    0000 I   003775 IDUM2    0000 I   003761 II       0000 I   003773 IIX      0000 I   003767 IMAX
     0000 I   003770 IMID     0000 I   003766 IMIN     0000 I   003771 IND      0000 I   003772 IOPT     0000 I   003735 IPRINT
     0000 I   003777 ISAVE    0000 I   003762 J        0000 I   003763 JJ       0000 I   003740 KN       0000 I   003741 KN1
     0000 I   003742 KN2      0000 I   003743 KN3      0000 R   000620 LSP      0000 R   000000 LSS      0000 R   000144 LSS1
     0000 I   003744 N        0000 R   000454 NDIP     0000 R   000310 NDIS     0000 I   003765 NLX      0000 I   003745 N1
     0000 I   003746 N2       0000 I   003747 N3       0000 I   003750 N4       0000 R   002114 PA       0000 R   002260 PADB
     0000 R   003736 PI       0000 R   004001 PY       0000 R   002570 RARO     0000 D   003420 RARO1    0000 R   002734 RFDFO
     0000 D   003422 RFDFO1   0000 R   001604 RO       0000 R   003752 S        0000 R   003751 T        0003 D   000004 X
     0000 D   003412 XO       0000 D   003424 XX

00101      1*          REAL LSS,LSS1,NDIS,NDIP,LSP
00103      2*          PARAMETER LMX=100
00104      3*          DIMENSION LSS(LMX),LSP(LMX),LSS1(LMX),NDIS(LMX),F(LMX),A(LMX)
00105      4*          DIMENSION DELNDI(LMX),FO(LMX),RO(LMX),ALPHA(LMX),NDIP(LMX),PA(LMX)
00106      5*          DIMENSION PADB(LMX),ADUM(LMX),RARO(LMX),RFDFO(LMX),ARG1(LMX),ANS1(
```

```
00106          1LMX)
00107          DOUBLE PRECISION ARO,GKDKO,X,E,AIN,XO,ARG,ANS,RARO1,RFDFO1
00110          DOUBLE PRECISION XX(LMX)
00111          COMMON/BLK/ARO,GKDKO,X,E
00112          ICARD=3
00113          IPRINT=4
00114          PI=3.14159
00114    C
00114    C       CARD   COLUMNS   FORMAT   ARGUMENT
00114    C       ----   -------   ------   --------
00114    C        1      1-5       I5      KN- NO. OF F VALUES
00114    C               6-10      I5      KN1- NO. OF A VALUES
00114    C               11-15     I5      KN2- NO. OF LSS VALUES
00114    C               16-20     I5      KN3- NO. OF FO/F VALUES +1
00114    C        2      1-10      F10.4   T
00114    C               11-20     F10.4   S
00114    C               21-30     F10.4   D
00114    C       IN THE FOLLOWING CARDS,IF MORE THAN ONE VALUE OF THE VARIABLES
00114    C       IS DESIRED (BASED ON CARD NO.1) THEN RELATED CARDS (ALL F'S) MUST
00114    C       BE GROUPED TOGETHER
00114    C        3      1-10      F10.5   F
00114    C        4      1-10      F10.5   A
00114    C        5      1-10      F10.5   LSS
00114    C        6      1-10      F10.5   FO/F
00114    C
00115          XO=.90909091D-2
00116          DO 8 I=1,86
00121          XX(I)=1.1*XO
00122        8 XO=XX(I)
00124          READ(ICARD,101) KN,KN1,KN2,KN3
00132      101 FORMAT(4I5)
00133          N=KN
00134          N1=KN1
00135          N2=KN2
00136          N3=KN3
00137          N4=N3+1
00140          RFDFO(1)=0.0
00141          PADB(1)=0.0
00142          NDIS(1)=0.0
00142    C
00142    C       IF POWER IS IN EXCESS OF 100KW CHANGE SCALE OF PADB PLOT
00142    C
00143          PADB(N4)=50.
00144          NDIS(N4)=50.
00145          RFDFO(N4)=0.0
00146          READ(ICARD,102) T,S,D
00153      102 FORMAT(3F10.4)
00154          READ(ICARD,100) (F(IA),IA=1,N)
00162          READ(ICARD,100) (A(IB),IB=1,N1)
00170          READ(ICARD,100) (LSS1(IC),IC=1,N2)
00176          READ(ICARD,100) (RFDFO(ID),ID=2,N3)
00204          C=1449.2+4.623*T-.0546*(T**2)+1.391*(S-35.)+.017 *D
00205          DO 1 I=1,KN
00210          DO 2 II=1,KN1
00213          DO 3 J=1,KN2
00216          WRITE(IPRINT,107)
00220          WRITE(IPRINT,103)
00222          WRITE(IPRINT,114)
```

```
00224              WRITE(IPRINT,104) T,D,S,C,A(II)
00233              WRITE(IPRINT,105)
00235              DO 4 JJ=2,KN3
00240              FO(JJ)=RFDFO(JJ)*F(I)
00241              E=(10.**3)*FO(JJ)
00242              FT=21.9*10.**(6.-(1520./(T+273.)))
00243              ALPHA(JJ)=(1./8.68)*(1.-(.00006332*D))*(1./914.4)*(.0186*((S*FT*(F
00243             1O(JJ)**2))/(FT**2+FO(JJ)**2))+(.0268*FO(JJ)**2/FT    )+((.1*FO(JJ)*
00243             2*2)/(1.+FO(JJ)**2)))
00244              NDIP(JJ)=10.*ALOG10((4.*PI*A(II)*E**2)/C**2)
00245              RO(JJ)=(A(II)*FO(JJ)*(10.**3))/C
00246              RAHO(JJ)=1.0/(2.*ALPHA(JJ)*RO(JJ))
00247              ADUM(JJ)=1.0/(2.*ALPHA(JJ))
00250              NLX=86
00251              IMIN=1
00252              IMAX=NLX
00253              IMID=NLX/2
00254              IND=NLX/2
00255              IOPT=0
00256           20 DO 5 IIX=1,91
00261              X=XX(IND)
00262              RAHO1=RAHO(JJ)
00263              RFDFO1=RFDFO(JJ)
00264              CALL SUN(RAHO1,RFDFO1,ARG,ANS,AIN,50)
00265              ARG1(JJ)=ARG
00266              ANS1(JJ)=ANS
00267              ARG1(JJ)=ARG1(JJ)+180.
00270              IF(ARG1(JJ).GT.210.) GO TO 210
00272              IF(ARG1(JJ).LT.140.) GO TO 220
00274              LSS(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))+ANS1(JJ)
00275              IF(ABS(LSS1(J)-LSS(JJ)).LT.1.) GO TO 200
00277              IF(IOPT.NE.0) GO TO 15
00301              IOPT=1
00302              IF(LSS1(J)-LSS(JJ)) 12,12,13
00305           12 ICONST=-1
00306              IDUM2=IMIN
00307              IDUM1=IMID
00310              GO TO 14
00311           13 ICONST=1
00312              IDUM1=IMAX
00313              IDUM2=IMID
00314           14 IND=(IDUM1+IDUM2+ICONST)/2
00315              ISAVE=IDUM2
00316              GO TO 5
00317           15 IF(LSS1(J)-LSS(JJ)) 17,17,16
00322           16 ICONST=1
00323              ISAVE=IND
00324              IDUM2=IND
00325              IND=(IDUM1+IDUM2+ICONST)/2
00326              GO TO 5
00327           17 ICONST=-1
00330              IDUM2=ISAVE
00331              IDUM1=IND
00332              IND=(IDUM1+IDUM2+ICONST)/2
00333            5 CONTINUE
00335          200 LSP(JJ)=ARG1(JJ)-20.*ALOG10(FO(JJ))
00336              PADB(JJ)=LSP(JJ)-70.8-NDIP(JJ)
00337              DUM=.1*PADB(JJ)
```

```
C0340          PA(JJ)=10.**DUM
C0341          NDIS(JJ)=(NDIP(JJ)+3.)-10.*ALOG10(1.+(RFDFO(JJ)*(2.*PI*ALPHA(JJ)*R
C0341         1O(JJ)+X)))
00342          DELNDI(JJ)=NDIS(JJ)-NDIP(JJ)
C0343          WRITE(IPRINT,106)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
0C343         1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ),PA(J
00343         2J),NDIS(JJ),DELNDI(JJ)
00365          GO TO 4
00366      210 LSP(JJ)=0.0
C0367          PADB(JJ)=0.0
C0370          NDIS(JJ)=0.0
00371          WRITE(IPRINT,112)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00371         1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00410          GO TO 4
C0411      220 LSP(JJ)=0.0
00412          PADB(JJ)=0.0
00413          NDIS(JJ)=0.0
00414          WRITE(IPRINT,113)  F(I),PADB(JJ),RFDFO(JJ),FO(JJ),ALPHA(JJ),ADUM(J
00414         1J),RO(JJ),RARO(JJ),NDIP(JJ),LSS(JJ),LSP(JJ),ARG1(JJ),ANS1(JJ)
00433        4 CONTINUE
C0433   C
C0433   C      THE PLOT ROUTINES ARE ON TAPE U183
C0433   C
C0435          CALL PLOTA(RFDFO,PADB,PY,N4,1H*,1H+,1,'PADB VS FO/F',2,IPRINT)
00436          CALL PLOTA(RFDFO,NDIS,PY,N4,1H*,1H+,1,'NDIS VS FO/F',2,IPRINT)
00437        3 CONTINUE
00441        2 CONTINUE
00443        1 CONTINUE
00445      100 FORMAT(F10.5)
C0446      103 FORMAT(50X,'T= WATER TEMPERATURE (DEGREES C)'
00446         1,//50X,'D= PROJECTOR DEPTH (METERS)',
C0446         3//50X,'S= SALINITY (PPT)',
00446         4//50X,'F= SECONDARY FREQUENCY (KHZ)',
00446         5//50X,'A= PROJECTOR AREA (SQ. METERS)',
C0446         6//50X,'FO/F= DOWNSHIFT RATIO',
00446         7//50X,'FO= PRIMARY FREQUENCY (KHZ)',
00446         8//50X,'AL= ABSORPTION CONSTANT (NEPERS/METER)',
00446         9//50X,'1/2AL= REACTION LIMIT (METERS)',
C0446         1//50X,'RO= RAYLIEGH DISTANCE (METERS)',
00446         2//50X,'NDIP= DIRECTIVITY INDEX-PRIMARY (DB)',
00446         3//50X,'LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)',
0C446         4//50X,'LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)',
00446         5//50X,'L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)',
C0446         6//50X,'G= PARAMETER GAIN (DB)',
C0446         7//50X,'PA= ACOUSTIC POWER PER TONE (WATTS)',
00446         8//50X,'ANDI= DIRECTIVITY GAIN (DB)',
00446         9//50X,'NDIS= SECONDARY DIRECTIVITY INDEX (DB)',
00446         1//50X,'PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE')
00447      104 FORMAT(//5X,'T= ',F5.0,//5X,'D= ',F8.1,//5X,'S= ',F4.0,//5X,'C= ',
00447         1F8.0,//5X,'A= ',F9.4)
00450      105 FORMAT(5X,'F',8X,'PADB',3X,'FO/F',5X,'FO',8X,'AL',5X,'1/2AL',5X,'R
00450         1O',4X,'1/2ALRO',1X,'NDIP',5X,'LSS',4X,'LSP',4X,'L*',5X,'G',5X,'PA(
00450         2WATTS)',1X,'NDIS',3X,'ANDI')
00451      106 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00451         11,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,1X,F9.1,1X,F5.1,2X,F5.1)
00452      107 FORMAT(49X,'PARAMETRIC SONAR DESIGN AND ANALYSIS')
00453      112 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00453         11,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* > 210.')
```

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00454    180*         113 FORMAT(F9.3,3X,F5.1,1X,F7.2,1X,F8.3,1X,F9.6,1X,F7.0,1X,F7.0,1X,F8.
00454    181*            1,1X,F5.1,1X,F6.1,1X,F6.1,1X,F6.1,1X,F5.1,10X,'L* < 140.')
00455    182*         114 FORMAT(1H1)
00456    183*             STOP
00457    184*             END

         END OF COMPILATION:        NO  DIAGNOSTICS.
```

APPENDIX B

SAMPLE EXAMPLE READOUT

The sample example tables and plots are shown here. These are as they appear on line out of the high speed printer associated with the computer.

```
PARAMETRIC SONAR DESIGN AND ANALYSIS
 T= WATER TEMPERATURE (DEGREES C)
D= PROJECTOR DEPTH (METERS)
S= SALINITY (PPT)
F= SECONDARY FREQUENCY (KHZ)
A= PROJECTOR AREA (SQ. METERS)
FO/F= DOWNSHIFT RATIO
FO= PRIMARY FREQUENCY (KHZ)
AL= ABSORPTION CONSTANT (NEPERS/METER)
1/2AL= REACTION LIMIT (METERS)
RO= RAYLIEGH DISTANCE (METERS)
NDIP= DIRECTIVITY INDEX-PRIMARY (DB)
LSS= SECONDARY SOURCE LEVEL (DB//MICROBAR-METER)
LSP= PRIMARY SOURCE LEVEL (DB//MICROBAR-METER)
L*= SCALED SOURCE LEVEL (DB//MICROBAR-METER-KHZ)
G= PARAMETER GAIN (DB)
PA= ACOUSTIC POWER PER TONE (WATTS)
ΔNDI= DIRECTIVITY GAIN (DB)
NDIS= SECONDARY DIRECTIVITY INDEX (DB)
PADB= ACOUSTIC POWER (DB//WATT) PER EACH PRIMARY TONE
```

T= 7.

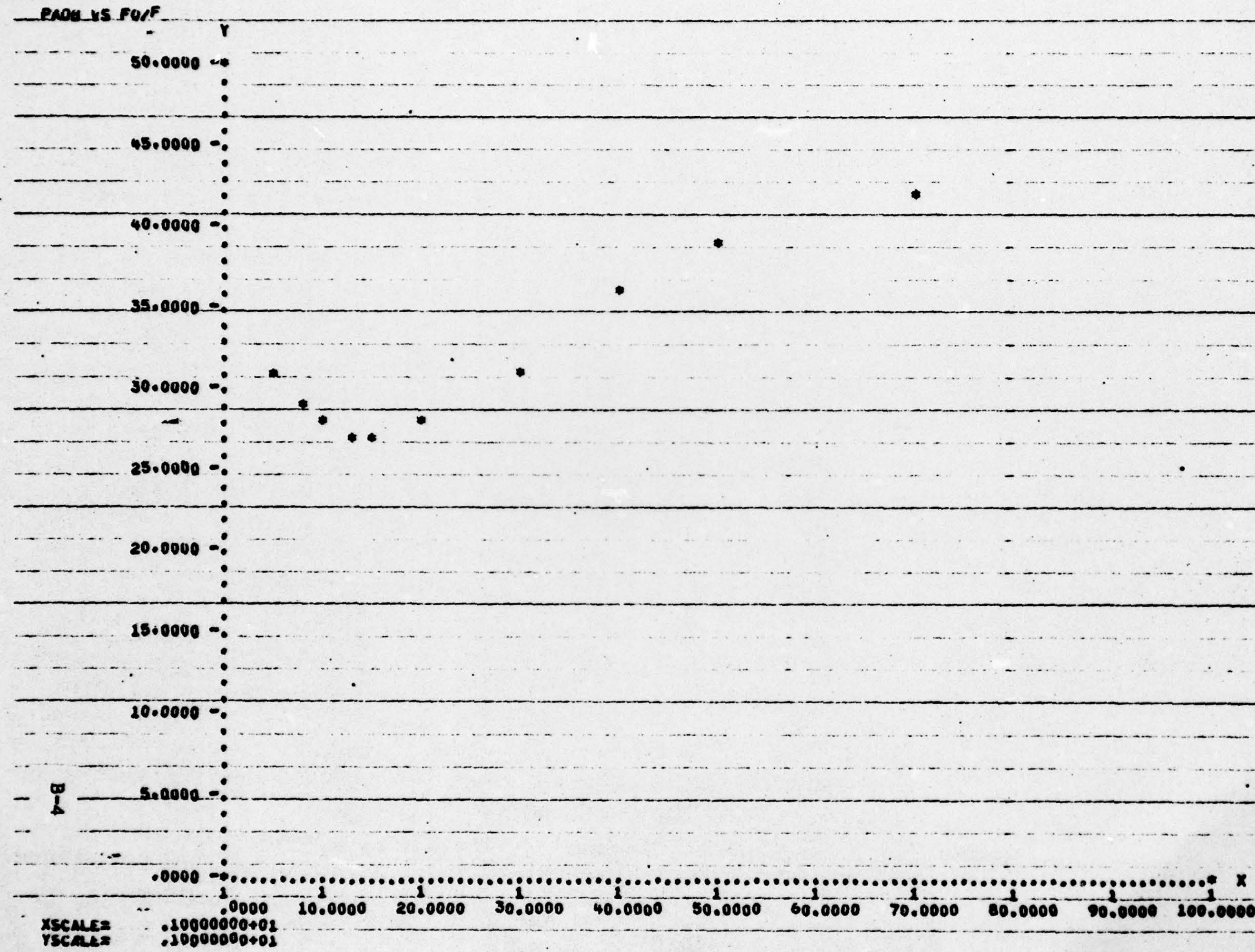
D= .0

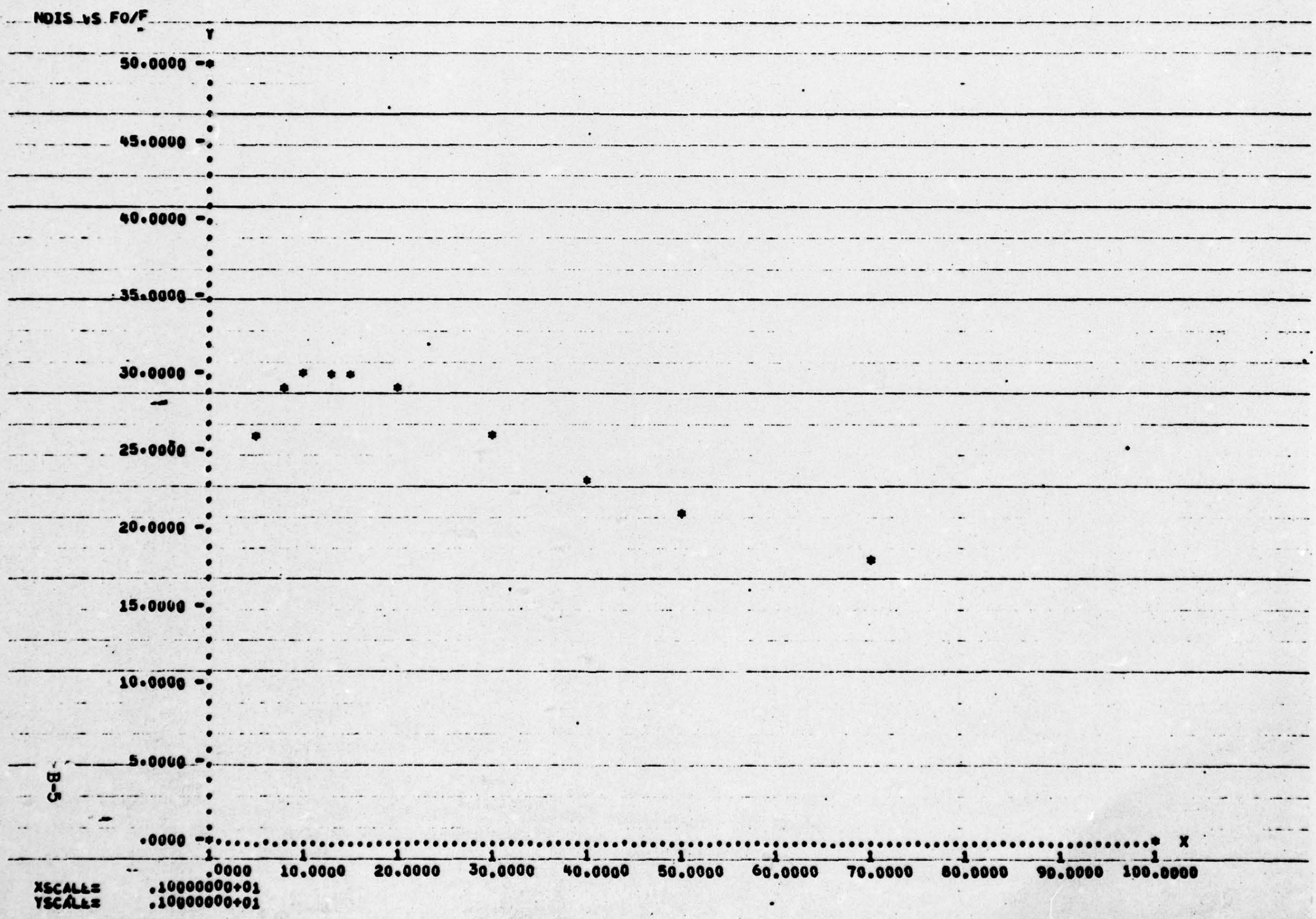
S= 35.

C= 1479.

A= .1964

F	PADB	FO/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	30.7	5.00	15.000	.000241	2079.	2.	1043.5	24.0	89.4	125.6	149.1	-36.2	1185.2	26.4	2.4
3.000	29.5	7.50	22.500	.000506	988.	3.	330.5	27.6	91.0	127.9	154.9	-36.9	889.0	28.8	1.3
3.000	27.8	10.00	30.000	.000846	591.	4.	148.3	30.1	89.8	128.7	158.2	-38.9	603.0	30.0	-.1
3.000	27.2	12.50	37.500	.001237	404.	5.	81.1	32.0	89.7	130.0	161.5	-40.3	529.4	30.3	-1.7
3.000	27.4	15.00	45.000	.001657	302.	6.	50.5	33.6	90.2	131.8	164.8	-41.5	547.3	30.0	-3.6
3.000	28.2	20.00	60.000	.002510	199.	8.	25.0	36.1	90.5	135.1	170.6	-44.6	657.6	29.0	-7.1
3.000	31.1	30.00	90.000	.004021	124.	12.	10.4	39.6	89.2	141.5	180.6	-52.3	1279.5	26.4	-13.2
3.000	36.0	40.00	120.000	.005186	96.	16.	6.1	42.1	89.5	148.9	190.5	-59.4	3987.5	23.2	-18.9
3.000	38.8	50.00	150.000	.006109	82.	20.	4.1	44.0	89.4	153.6	197.1	-64.2	7504.9	21.0	-23.0
3.000	42.0	70.00	210.000	.007653	65.	28.	2.3	47.0	89.3	159.8	206.2	-70.5	15902.7	18.1	-28.8
3.000	.0	100.00	300.000	.009969	50.	40.	1.3	50.1	83.0	.0	210.4	-76.9	L* > 210.		


PAOH vS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01


NDIS vS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
5.0000
.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

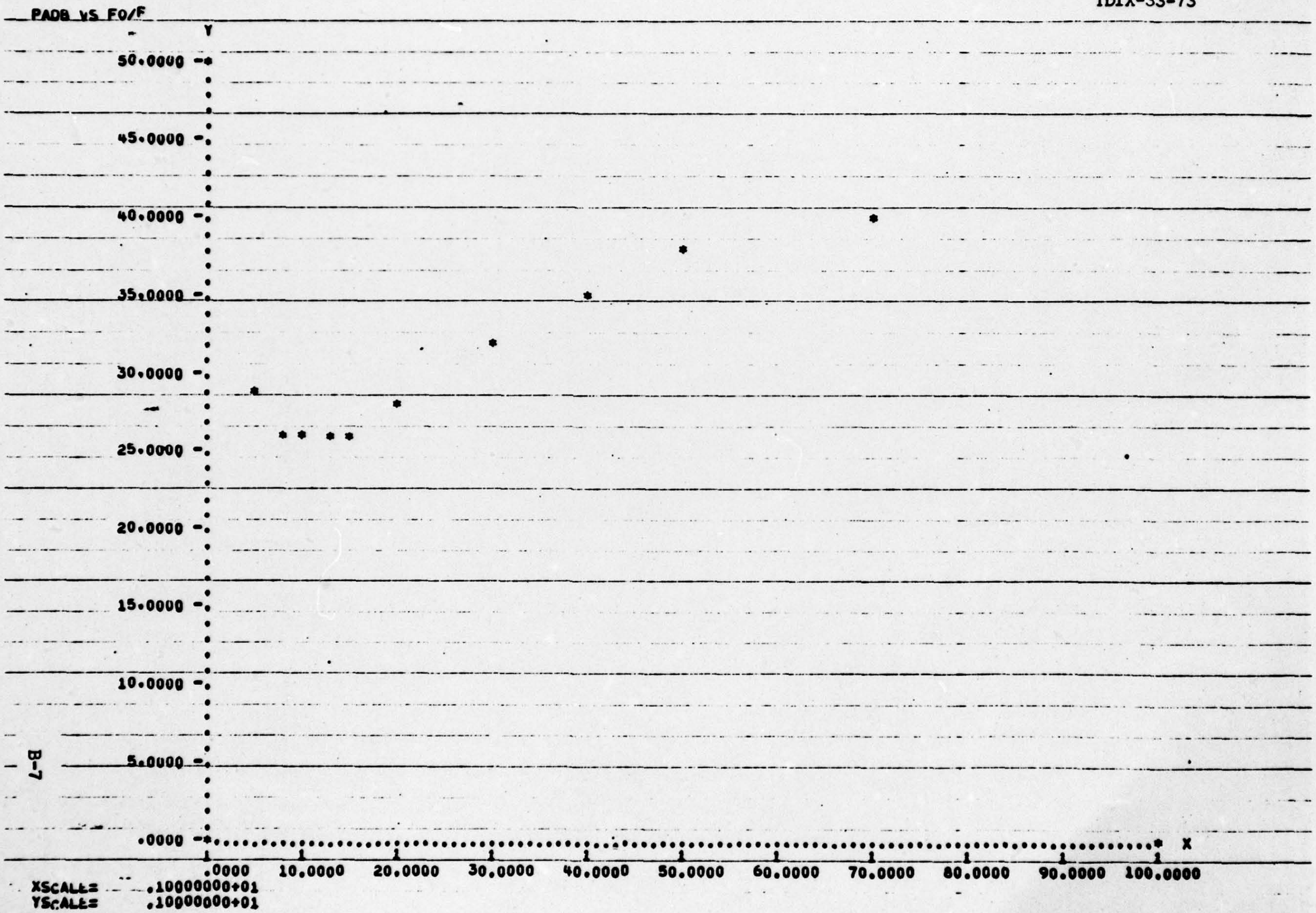
D= .0

S= 35.

C= 1479.

A= .3927

F	PAUG	FU/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	26.6	5.00	15.000	.000241	2079.	4.	521.9	27.1	89.9	126.4	149.9	-36.5	717.2	29.3	2.3
3.000	26.5	7.50	22.500	.000506	988.	6.	165.3	30.6	89.4	127.9	154.9	-38.5	444.6	31.6	1.1
3.000	26.4	10.00	30.000	.000846	591.	8.	74.1	33.1	90.9	130.3	159.9	-39.4	441.5	32.3	-.8
3.000	25.9	12.50	37.500	.001257	404.	10.	40.6	35.0	90.2	131.7	163.2	-41.5	387.7	32.3	-2.8
3.000	26.0	15.00	45.000	.001657	302.	12.	25.3	36.6	90.1	133.4	166.5	-43.3	400.8	31.8	-4.8
3.000	27.7	20.00	60.000	.002510	199.	16.	12.5	39.1	90.6	137.6	173.1	-47.0	582.7	30.3	-8.8
3.000	32.2	30.00	90.000	.004021	124.	24.	5.2	42.6	90.6	145.6	184.7	-55.1	1659.7	27.1	-15.5
3.000	35.5	40.00	120.000	.005106	98.	32.	3.0	45.1	90.3	151.4	193.0	-61.1	3532.9	24.7	-20.4
3.000	36.2	50.00	150.000	.006109	82.	40.	2.1	47.1	90.8	156.1	199.6	-65.2	6649.4	22.6	-24.4
3.000	39.8	70.00	210.000	.007053	65.	56.	1.2	50.0	89.5	160.6	207.1	-71.1	9623.6	20.5	-29.5
3.000	.0	100.00	300.000	.007969	50.	80.	.6	53.1	82.2	.0	210.4	-77.7	L* > 210.		


PADB VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
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.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
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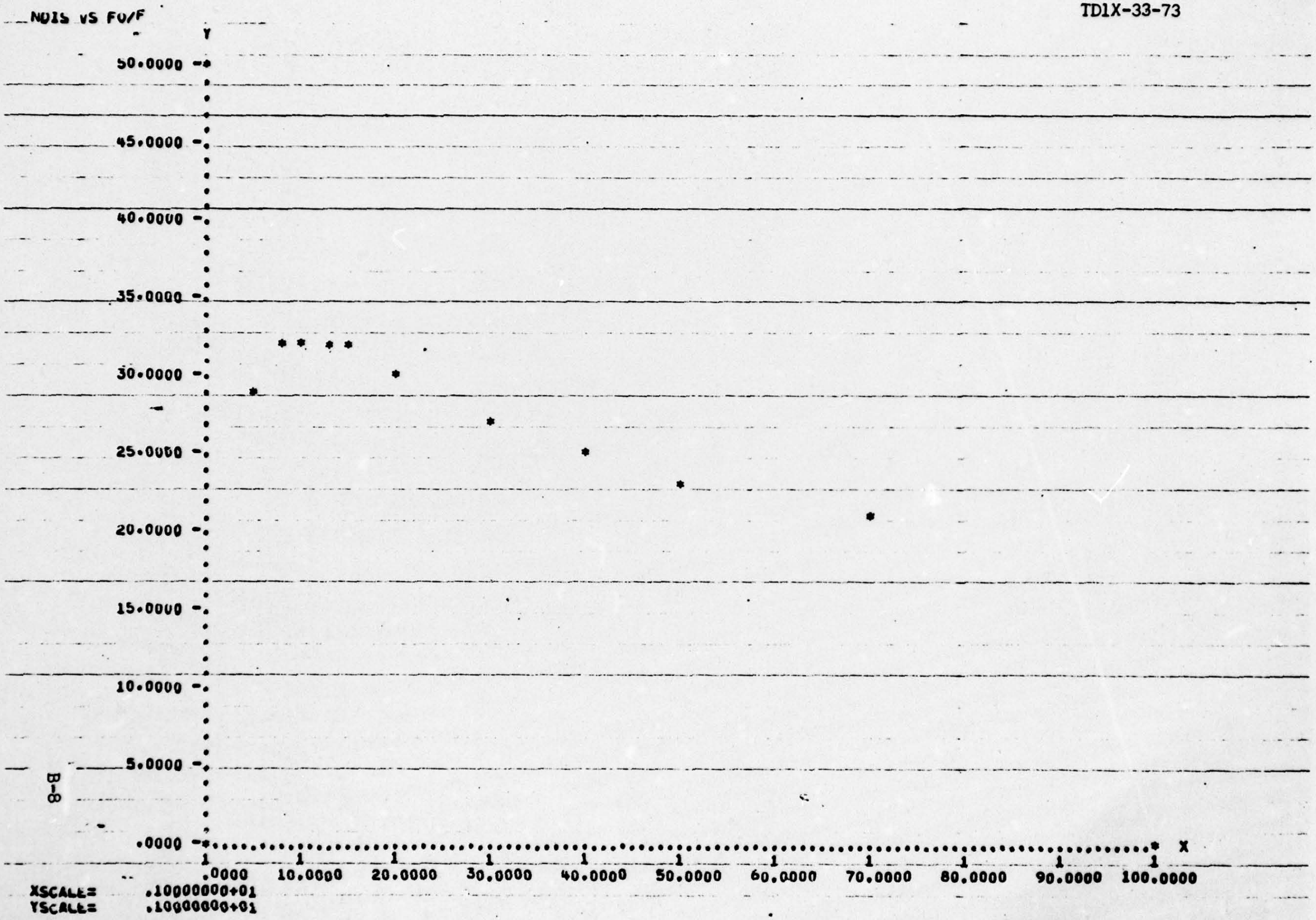
YSCALE= .10000000+01


NDIS VS FO/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
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.0000
X
.0000
10.0000
20.0000
30.0000
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
XSCALE= .10000000+01
YSCALE= .10000000+01

T= 7.

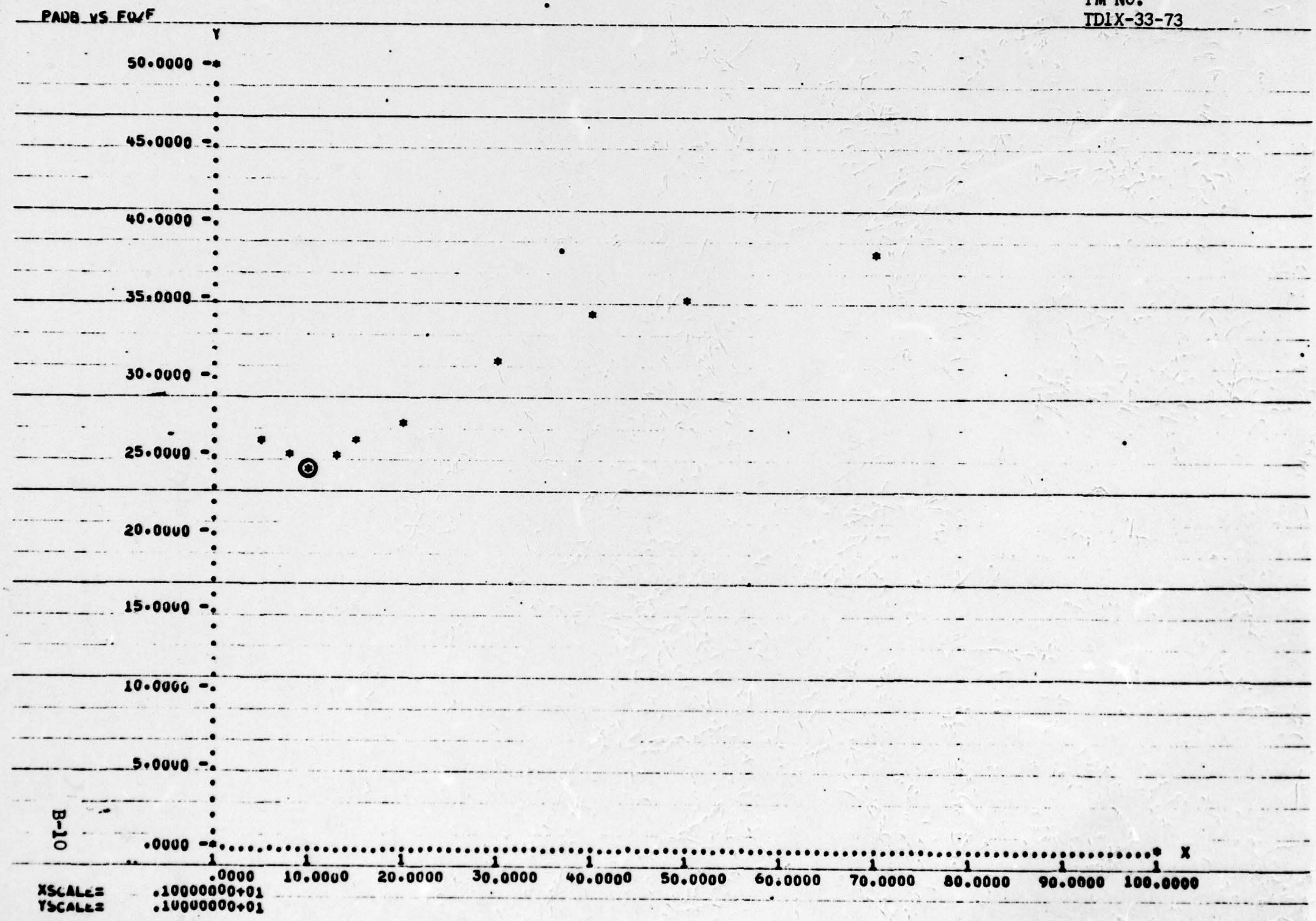
D= .0

S= 35.

C= 1479.

A= .7854

F	PADB	FO/F	FO	AL	1/2AL	RO	1/2ALRO	NDIP	LSS	LSP	L*	G	PA(WATTS)	NDIS	ΔNDI
3.000	26.6	5.00	15.000	.000241	2079.	8.	260.9	30.1	90.2	127.2	150.8	-37.0	433.9	32.2	2.1
3.000	25.1	7.50	22.500	.000506	988.	12.	82.7	33.6	90.7	129.5	156.6	-38.8	325.5	34.1	.5
3.000	24.3	10.00	30.000	.000846	591.	16.	37.1	36.1	89.9	131.2	160.7	-41.2	267.1	34.4	-1.7
3.000	24.5	12.50	37.500	.001237	404.	20.	20.3	38.0	90.1	133.4	164.8	-43.3	283.8	33.9	-4.1
3.000	25.5	15.00	45.000	.001657	302.	24.	12.6	39.6	90.7	135.9	169.0	-45.2	355.0	33.1	-6.5
3.000	27.1	20.00	60.000	.002510	199.	32.	6.3	42.1	90.2	140.0	175.6	-49.9	516.1	31.5	-10.6
3.000	30.6	30.00	90.000	.004021	124.	48.	2.6	45.6	89.6	147.3	186.4	-57.7	1215.0	28.6	-17.0
3.000	34.1	40.00	120.000	.005186	96.	64.	1.5	48.1	90.3	153.1	194.6	-62.8	2586.3	26.4	-21.8
3.000	35.2	50.00	150.000	.006109	82.	80.	1.0	50.1	89.5	156.1	199.6	-66.6	3324.7	25.1	-25.0
3.000	38.5	70.00	210.000	.007653	65.	112.	.6	53.0	90.4	162.3	208.7	-71.8	7044.9	22.4	-30.6
3.000	.0	100.00	300.000	.009969	50.	159.	.3	56.1	81.0	.0	210.4	-78.8	L* > 210.		


PADB VS FU/F
Y
50.0000
45.0000
40.0000
35.0000
30.0000
25.0000
20.0000
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10.0000
5.0000
.0000
.0000
10.0000
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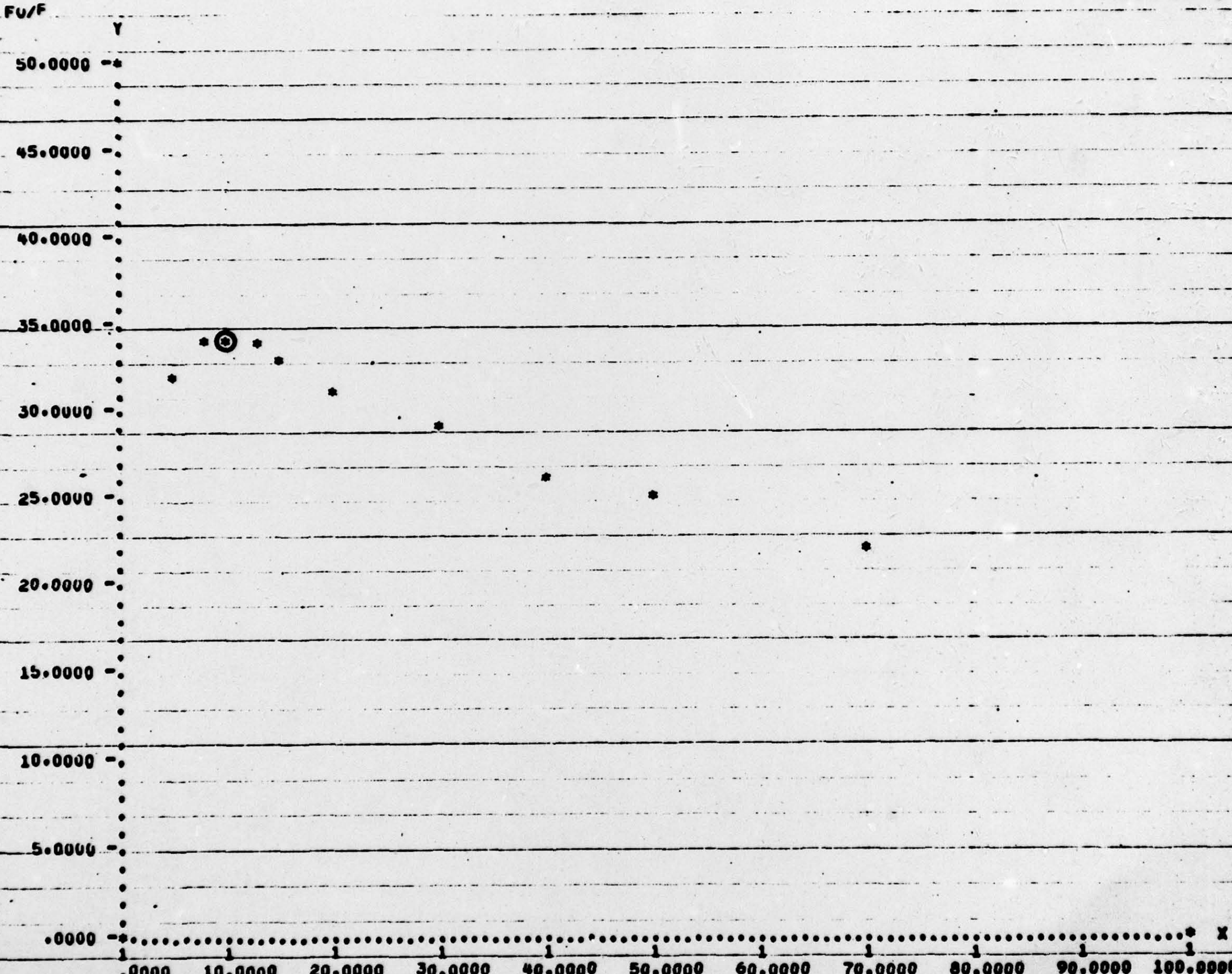
40.0000
50.0000
60.0000
70.0000
80.0000
90.0000
100.0000
X
XSCALE= .10000000+01
YSCALE= .10000000+01

NDIS VS FU/F



XSCALE= .10000000+01
YSCALE= .10000000+01